ECOPHYSIOLOGICAL RESPONSES OF RHIZOMA PEANUT TO GRAZING MANAGEMENT

BY

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To my mother Aurora:

Who dedicated many years of her life to make me understand the value of hard work, persistence, and education.

To my wife Caty:

Who contributed significantly to the successful completion of my program with her love and support throughout all of these years.

To my son Alfonso:

For being one of my most special friends.

To my daughters Alejandra and Alfonsina:

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Major Department: Agronomy

Poor persistence of many tropical forage legumes under grazing has limited their use. Lack of understanding and implementation of appropriate grazing management has contributed to this problem. Rhizoma peanut (_Arachis glabrata_ Benth.) is a promising pasture legume for warm climates, but little information is available on grazing management of peanut.

Studies were conducted in 1988 and 1989 near Gainesville, FL, to determine optimum grazing management for peanut. Treatments included all combinations of three levels of postgraze residual dry matter (RDM; 500, 1500, and 2500 kg ha^{-1}) with four levels of length of grazing cycle (GC; 7, 21, 42, and 63 d). Data were analyzed by response surface methodology using a second order polynomial model.

There was a GC by RDM interaction for peanut herbage accumulation (HA). At low RDM, increasing GC increased HA, but GC had less effect as RDM increased. Maximum levels for peanut HA (9600 kg ha^{-1}) were found with an RDM between 1100 and 2400 kg ha^{-1}, and GC longer than 42 d. In this range, peanut percentage in HA was maximized also. Poor legume persistence and productivity were found with low RDM and short GC treatments which were characterized by low light interception after grazing due to intensive defoliation. Plants were unable to produce enough assimilate from residual leaf to support regrowth, therefore, rhizome total non-structural carbohydrate (TNC) reserves and rhizome mass were gradually depleted. To maintain a peanut percentage of 80% or greater, these data suggest that RDM should be approximately 1500 kg ha^{-1} or higher, if GC is longer than 42 d, or higher than 2000 kg ha^{-1} if GC is shorter than 35 d. In these ranges, rhizome mass and TNC reserves are expected to remain high enough to allow maximum persistence and productivity. Total canopy digestibility (660 to 700 g kg^{-1}) and crude protein (180 g kg^{-1}) were near maximum at RDM and GC levels where peanut persisted best.

Unlike most tropical legumes, rhizoma peanut persists and performs well under a relatively wide range of grazing managements. Thus, even though rhizoma peanut establishment is slow, peanut can be considered as a promising forage legume for tropical and subtropical regions.

CHAPTER I

INTRODUCTION

Variation in seasonal distribution of pasture production and low quality of the forage produced have been recognized as major factors limiting productivity of tropical livestock systems. One management alternative that has been suggested to aid in overcoming this problem is use of forage legumes. Advantages of forage legumes include addition of symbiotic N to the soil and the contribution of high-quality forage to the animal diet (Mott, 1981; Kretschmer, 1985; and Whiteman, 1980).

Use of forage legumes in a grazing system requires more careful management than that needed for a grass monoculture. Mott (1981) stated that grass-legume associations in tropical environments have been only moderately successful. Maraschin et al. (1981) concluded that forage legumes have played only a minor role in the tropics primarily due to poor persistence under grazing. Lack of understanding or implementation of proper grazing management has contributed to this problem.

In the last three decades many papers have been published describing the effects of forage legumes on animal performance. In many of these studies, however, no detailed canopy characterization is reported, while in many others the contribution of legume to total biomass production decreased with time; thus the association was not sustainable under that management. Knowledge of plant responses to grazing stress is an indispensable tool in planning successful grazing systems, i.e., those in which plant persistence, pasture productivity, and nutritive value are maintained at appropriate levels over time.

From this perspective, a goal of forage researchers has been to identify persistent forage plants that contribute significantly to pasture production in terms of herbage quantity and nutritive value. In 1979, 'Florigraze' rhizoma peanut (Arachis glabrata Benth.) was released to producers (Prine et al., 1981a). Animal performance trials conducted by Sollenberger et al. (1989) have demonstrated exceptional animal performance (0.93 kg head^{-1} d^{-1}) and good persistence of Florigraze under moderate levels of grazing intensity. Several clipping trials have reported little reduction in nutritive value of peanut as maturity increases (Beltranena et al., 1980 and 1981). Based on field observations and its performance in these studies, it has been suggested that rhizoma peanut could persist well under a relatively wide range of grazing management. Knowledge of peanut responses to grazing stress is limited, however, but needed by producers to obtain the greatest benefit from use of peanut pastures. This knowledge would allow grazing management decisions to be made with an understanding of their potential effect on stand life, peanut productivity, and nutritive value. Appropriate compromises between plant and animal requirements can then be determined.

For these reasons a plant response to grazing stress study was conducted. The overall objective was to determine the range of grazing management under which rhizoma peanut persists well, and which optimizes pasture productivity and nutritive value. Detailed characterization of crop canopy and growth responses was used to define these ranges and to explain the success or failure of specific management strategies.

CHAPTER II
LITERATURE REVIEW

Importance of Forages in Tropical Livestock Systems

In most tropical regions of the world, grazed pastures are the only source of feed for ruminants, since other sources are not available or are too costly. It has been estimated that 90% of the feed energy consumed by herbivorous livestock is obtained from forages (Fitzhugh et al., 1978, cited by Henzell, 1981), and grazed pastures provide the cheapest source of feed for ruminants (Morley, 1981). There is an increasing trend, however, for grasslands to be restricted to non-arable land. This is occurring due to population pressures and the fact that the conversion of solar energy to human food is less efficient through ruminants than if plant products are grown for direct human consumption (Mannetje, 1978). This comparison is somewhat misleading, however, because it fails to consider that productive capacity of land varies considerably. Over half the world's land mass is non-arable, and much of the arable land cannot sustain continuous high-yield cropping. Thus, sustained agricultural production on these soils is possible only if perennial forages are grown and then used by livestock to produce animal products for human consumption.

Major limitations of tropical forage-livestock systems include seasonality of forage production, capacity of plants to produce dry matter, low legume contribution, and low forage quality. Maximum pasture productivity in the tropics has been reported to be in the order of 80 Mg ha^{-1} of dry matter, but this level of production can be obtained only with improved species under optimum conditions of light, temperature, soil nutrients, and water availability. In the wet-dry tropics, both moisture and temperature may become limiting, with a reduction in maximum production to about 30 Mg ha^{-1} yr^{-1} (Mott, 1981). A high percentage of this production occurs during the wet season. According to Mannetje (1978), seasonality of production results in low carrying capacities because stocking rate must be chosen based on the period of lowest forage availability. In terms of forage quality, Mott (1981) pointed out that a large proportion of digestible energy intake is used for maintenance instead of for production, because of the low quality potential of the herbage. Hence, animal production in the tropics is low due to periods of low forage availability and low forage quality (Moore and Mott, 1973).

There are several alternatives that may be considered for improving productivity of tropical livestock systems. These include use of adapted high yielding legumes and drought-tolerant grasses which can extend the grazing season, use of stored or preserved forages harvested during the rainy season and fed during the dry season, and grazing management strategies to optimize the utilization of the pasture.

This review will focus primarily on use of legumes and their response to grazing management. Specific aspects about establishment, management, and utilization of rhizoma peanut (Arachis glabrata Benth.) will be considered also.

Tropical Legumes

The legume family is divided into three groups or subfamilies; Mimosoideae, woody plants and herbs with regular flowers; Caesalpinioideae, plants with irregular flowers; Papilionoideae, herbaceous and woody plants with a distinctive papilionate or butterfly-shaped flower. Most of the forage legumes belong to the latter family (Crowder and Chheda, 1982).

Contribution

Nitrogen deficiency is a major limitation to pasture productivity in the tropics. Use of synthetic N fertilizers is not practical in many cases because of their cost and unavailability in tropical regions. Under these conditions, biological N fixation by legumes and their contribution to animal diets assumes an important role (Mott 1981; Whiteman 1980; and Kretschmer, 1985).

Nitrogen Fixation

Initiation of N fixation depends upon the presence of an effective strain of Rhizobium that infects the legume root. Most tropical legumes are readily infected with a wide range of rhizobia types commonly present in soils of the tropics and subtropics. Some tropical legumes, however, require specific types of Rhizobium in order to effectively nodulate and initiate N fixation (Crowder and Chheda, 1982). Biological N fixation can be affected by environmental factors such as soil moisture and chemical properties, temperature, light intensity, and daylength (Shaw and Bryan, 1976).

The N contribution of the legume to the pasture system is primarily a function of the amount and vigor of the legume component, but is modified by the time over which the nodule system is active and fixing N (Whiteman, 1975). Morris and Date (1976) indicate that quantity of N fixed often is between 100 and 200 kg ha^{-1} yr^{-1}. Values of 570 kg ha^{-1} yr^{-1} of N fixed have been reported with Leucaena leucocephala in Australia (Hutton and Bonner, 1960), but this level is rarely if ever attained under producer conditions.

In grass-legume associations, the grass may gain access to nitrogenous compounds fixed by the legume. Transfer of N to the associated grass is mainly by sloughing off and decay of nodules into the soil. Decomposition of legume residues is also an important source of N for associated plants (Crowder and Chheda, 1980). Valentim et al. (1986) reported increases in dry matter production of 100 to 300% when 'Pensacola' bahiagrass (*Paspalum notatum* Flugge), Tifton 'Hybrid-8' bermudagrass [*Cynodon dactylon* (L.) Pers.], and 'Survenola' digitgrass (*Digitaria* x *umfolozi* Hall) were associated with rhizoma peanut, compared with yields obtained when the grasses received no N fertilization and were grown in pure stands. Kaiser (1989) reported that the mixture of eastern gamagrass (*Tripsacum dactyloides* L.) and bigflower vetch (*Vicia grandiflora* L.) had a higher energy output to input ratio than did tall fescue (*Festuca arundinacea* Schreb.) which was fertilized with N.

Anatomical and Physiological Characteristics

Tropical pasture plants can be divided into two groups: C_4 grasses and C_3 legumes. These categories of plants are very different in terms of anatomical and physiological features, and these differences result in legumes requiring special consideration in pasture ecosystems.

There are important anatomical characteristics that contribute to the differences between C_3 and C_4 plants. The C_4 grasses have the so-called "Kranz" anatomy, consisting of tightly packed mesophyll cells surrounding large chloroplast-containing vascular bundle sheath cells. In C_3 legumes, the mesophyll consists of a palisade parenchyma cell layer and scattered spongy parenchyma cells, while the vascular bundles have small bundle sheath cells which do not contain chloroplasts.

In both temperate and tropical species, the primary CO_2 fixation reaction takes place in the chloroplasts of the mesophyll cells. In C_3 plants, one molecule of CO_2 combines with one molecule of ribulose 1,5 bis-phosphate (RuBP), through the catalytic action of the enzyme RuBP-carboxylase-oxygenase (Rubisco), to give two molecules of 3-phosphoglycerate. In C_4 plants the primary CO_2 reaction is catalyzed by phosphoenolpyruvate (PEP)-carboxylase, an enzyme with a high affinity for CO_2. The resultant product is the four-carbon compound oxaloacetic acid. In C_4 plants, the fixed carbon is "pumped" as malate or aspartate into chlorophyll-rich bundle sheath cells. Here enzymatic decarboxylation leads to locally high concentrations of CO_2, which greatly benefit the secondary carbon fixation through the action of Rubisco (Robson, 1981).

Differences associated with the pathways of carbon fixation were summarized by Whiteman (1980) and Ludlow (1985) as the following:

a). The CO_2 acceptor molecule in C_4 plants is PEP, and it is associated with the enzyme PEP-carboxylase that is highly reactive with CO_2. This is one reason why C_4 plants are able to fix larger amounts of CO_2 than do C_3 plants, where the CO_2 acceptor molecule is RuBP and its associated enzyme Rubisco.

b). PEP-carboxylase is not inhibited by O_2, but in contrast, Rubisco is somewhat inhibited.

c). Optimum temperature for PEP-carboxylase activity is between 30 and 35^{o}C and for Rubisco is between 20 and 25^{o}C.

d). The physiological consequences are the following: (1) rate of photosynthesis is higher in C_4 plants than in C_3, (2) light saturation in C_4 plants is approximately at full sunlight, while in C_3 it is approximately at one-half full sunlight, (3) there is no apparent photorespiration in C_4 plants, while there is significant photorespiration in C_3 plants, and 4) CO_2 compensation point is near zero in C_4 plants, while in C_3 plants it is about 37 mg kg^{-1} (Ludlow and Wilson, 1972).

In absence of climatic constraints and when water and mineral nutrients are plentiful, the upper limit of dry matter production is set by the amount of solar radiation received (Ludlow, 1985). An important consequence of the anatomical and physiological differences between C_3 legumes and C_4 grasses is that tropical grasses can achieve up to three times the photosynthetic rate of tropical legumes (Ludlow and Wilson, 1970).

Potential dry matter production for C_4 plants in the wet tropics is 63 g m^{-2} d^{-1} where the average daily solar radiation is 17.2 MJ m^{-2} d^{-1}. This would result in an annual dry matter production of 230 Mg ha^{-1} if this growth rate could be sustained for a year (Ludlow, 1985). Under conditions where illumination may be limiting, however, C_3 plants may have an advantage over C_4s, since their requirement for light is lower (Whiteman, 1980). Ludlow et al. (1974) reported that shading affected the growth rate of grasses more than that of legumes. The greater shading effect occurred due to a decrease in net assimilation rate, and to a lesser extent, from a smaller compensatory increase in leaf area ratio in grasses than in legumes. The greater sensitivity of net assimilation rate of grasses to shading arose from a stronger dependence of the photosynthetic rate on illuminance.

In this context, the lower crop growth rate of legumes compared to grasses presents a disadvantage for legumes especially when they are grown in a mixture. As a consequence, grazing management requirements for C_3 legumes must be, in most cases, different than for C_4 grasses. This represents a problem when managing grass-legume mixtures.

Grazing Management

The importance of grazing management to achieve maximum pasture or animal productivity is well recognized. Published results, however, show little agreement on any optimum management for a particular pasture system. The lack of agreement reflects the complexity of understanding entire ecosystems, which are characterized by many interactions (Vickery, 1980).

According to Sollenberger and Chambliss (1989) ".... the most important choices to be made in designing a grazing management system are how close and how often the pastures are going to be grazed. These choices affect pasture performance which subsequently determines how well the animals will perform". In this context, selection of the grazing management to be used strongly influences profitability of the livestock operation.

Some important objectives of a grazing management system have been suggested by Sollenberger and Chambliss (1989) as the following:

a). High production of forage per land unit.
b). Efficient use of the forage produced by the grazing animals.
c). Long-term persistence of the pasture.
d). High level of production per animal and per hectare.

e). Match the needs of the producer in terms of profit margin, level of risk, and management skill.

Pasture Persistence

The association of C_4 grasses with C_3 legumes in the tropics has been only moderately successful (Mott, 1981). Legume-based pastures have played a minor role in livestock production in the tropics and subtropics because of poor persistence of tropical legumes under grazing (Maraschin et al., 1981). Intolerance of legumes to grazing stress and grass competition has been reported also in Florida by Pitman and Kretschmer (1984), and by Pitman et al. (1986 and 1988).

The productivity and botanical composition of pastures can be rapidly and substantially altered by grazing animals (Watkin and Clements, 1978). The principal effects of grazing on pasture plants are due to defoliation, trampling, and deposition of waste. A valuable forage for grazing must survive these stresses and regrow to face them again (Sollenberger and Chambliss, 1989).

Defoliation is probably the most important effect of grazing on the pasture (Watkin and Clements, 1978). Defoliation is considered as a disturbance, and is defined as the removal of any part of the plant shoot. Removal may be by grazing, cutting, fire, cultivation, herbicide, treading, fouling of herbage or by environmental factors such as frost, drought, and wind (Harris, 1978).

Characterization of defoliation involves three factors: (a) frequency, the time interval between successive defoliations; (b) intensity, defined as how close the pastures are grazed, but also including terms such as severity, duration, percentage of utilization, and residual leaf area, and (c) timing, which relates to the developmental phases of plants and season of year when defoliation occurs (Harris, 1978).

Grazing intensity and rest period

Sollenberger and Chambliss (1989) suggested that the most important tools available for grazing management are the selection of grazing intensity and grazing frequency. They proposed that grazing intensity determines whether plants will have energy reserves, leaves, or living buds available for regrowth after grazing. There is often an interaction between grazing intensity and frequency, with longer rest periods required when pastures are grazed closely and little or no photosynthetically active material is left after grazing.

Different opinions can be found in the literature about the major factors affecting persistence and contribution of botanical components to the pasture sward. Canudas-Lara (1988), evaluating an association of 'Pangola' digitgrass (Digitaria decumbens Stent) and 'Clarence' glycine [Neonotonia wightii (R. Grah. ex Wightii and Arn.) Lackey], found that postgraze residual dry matter was the major factor affecting botanical composition of the pasture and persistence of glycine. Maraschin et al. (1981), examined a mixture of Paspalum guenoarum (Arech.) and Desmodium intortum (Mill.) and found that long rest periods were required to maintain D. intortum and P. guenoarum as active components of the pasture sward. Similar results were obtained by Jones (1979) and Bryan and Evans (1973) who observed that climbing legumes were favored by light grazing and long rest intervals.

Different results were obtained by Santillan (1983) in a legume-grass pasture composed of glycine, centro (Centrosema pubescens Benth.), guineagrass (Panicum maximum Jacq.), and elephantgrass (Pennisetum purpureum Schumach). Legume yields and percentages were highly sensitive to length of rest period and less sensitive to grazing pressure. Short rest periods favored the legumes. This occurred because of the growth habit of the grasses, since short rest periods reduced grass competition for light and allowed the legume to perform better. Similar results were obtained by Abramides et al. (1983) in an association of Setaria anceps (Stapf ex Massey) and Galactia striata (Jack.) Urb. They evaluated three grazing systems: a) continuous grazing, b) rotational grazing with 7 d of grazing and 14 d of rest, and c) rotational grazing with 7 d of grazing and 28 d rest. The stocking rates for the three systems were 3 and 2 steers ha^{-1} for the rainy and dry seasons. Amount of forage produced was similar for the three systems, but there was a linear ($P<0.01$) reduction of the legume as the rest period was increased. This occurred due to shading from the tall-growing grass.

Numerous authors have reported decreases contribution of the legume as stocking rate increased (Cowan and Davison, 1982; Cowan et al., 1975; Jones and Clements, 1987; Davison and Brown, 1985). Humphreys (1980) suggested that twining legumes are not tolerant to heavy grazing pressure and rarely persist in humid environments where the year-round stocking rate exceeds 2.5 head ha^{-1}. Davison and Brown (1985) found that for an association of 'Gatton' panic (Panicum maximum Jacq.), glycine, and 'Greenleaf' desmodium (Desmodium intortum Mill.), a stocking rate of 2 cows ha^{-1} led to a continuing decline in legume percentage and yield. Legume contribution decreased from 28% (1055 kg of dry matter ha^{-1}) in autumn 1977 to 3% (118 kg of dry matter ha^{-1}) by autumn 1981. Destocking of this area in spring 1981 produced a rapid recovery of the legume.

Light interception and regrowth after defoliation

One important consequence of defoliation intensity is its effect on the amount of forage left in the pasture after grazing. Thomas (1980) and Hodgson (1979) suggested that the remaining forage be referred to as residual herbage.

Residual herbage determines in part the amount of photosynthetically active tissue available to intercept light for photosynthesis and subsequent growth.

Vickery (1980) and Ward and Blaser (1961) mentioned that the relationship between leaf area, light interception, and subsequent growth in plant communities is very important, because the primary synthesis of dry matter results from the photosynthetic activities of the leaves. Therefore, efficiency of this process depends to a large degree on the size, shape, position, and structure of photosynthetic organs. This introduces the concept of leaf area index (LAI) which is defined as the ratio of leaf area of the plant canopy to the area of land beneath that canopy. It has been observed that as LAI increases, growth rate increases until 95% of all incident light is intercepted, which occurs when LAI is about 3.5 in red clover (Trifolium pratense L.) (Nosberger and Joggi, 1981). Similar results illustrating the relationship between LAI, light interception, and growth have been reported by Leafe et al. (1974) and Deinum et al. (1981).

Gomide (1981) indicated that forage plants differ considerably in their ability to recover from grazing. Summarizing the opinions of several authors he suggested that factors determining the regrowth of forage are: a) shoot apex survival, b) leaf area, c) non-structural carbohydrate content, and d) tillering potential.

Brougham (1955) studied an association of ryegrass (Lolium perenne L. x Lolium multiflorum Lam.), red clover, and white clover (Trifolium repens L.) to determine the nature of the pasture growth curve. He found that these curves showed three distinct phases. For approximately 3 wk following defoliation, growth rate increased, then for 5 wk it was constant, and thereafter it declined. He suggested that the duration of the first phase of growth was related to leaf area and light interception, and that this growth phase continued until there was sufficient leaf area to intercept all incident light.

On basis of the previous study, Brougham (1956) evaluated the effect of cutting heights (2.5, 7.5, and 12.5 cm) on light interception and residual leaf area after defoliation and the rate of growth of a Lolium perenne (L.) x Lolium multiflorum (Lam.)-Trifolium pratense L. association. Light interception 4 d after defoliation was 12.7, 71.6 and 96.5%, for the cutting heights of 2.5, 7.5, and 12.5 cm, which also corresponded to LAI of 1.74, 3.54, and 5.42. He found that differences in light interception disappeared after 24 d (all were 95% or over). Dry matter yield and LAI were still different, however, being 623, 1042, and 1507 kg acre^{-1}, and 4.8, 5.8, and 8.4 for the 2.5-, 7.5-, and 12.5-cm cutting heights, respectively. In this study the rate of increase of herbage dry weight per unit area of leaf (leaf efficiency) was greatly influenced by intensity of defoliation. Efficiency was initially lower following severe defoliation than in the other treatments. It increased rapidly to a maximum and thereafter declined gradually. The rate of pasture growth increased until complete light interception was approached, and thereafter an almost constant maximum rate was sustained. Similar results were reported by Pearse et al. (1965) for Dactylis glomerata (L.). More than 90% of light was intercepted at LAI 3. Net photosynthesis was affected by LAI and the maximum was recorded at LAI of 5.

Albrecht and Boote (1985) conducted an experiment to evaluate regrowth characteristics of aeschynomene (Aeschynomene americana L.) and limpograss [Hemarthria altissima (Poir.) Stapf et C.E. Hubb.] after defoliation. They measured LAI, light interception, and canopy carbon exchange rate (CER) over an 8-wk period of regrowth following defoliation to 9 or 18 cm. For both species, the taller the stubble height the greater number of viable buds that remained after clipping and the higher the rate of recovery of canopy leaf area. Amount of light intercepted for the 18-cm treatment increased more rapidly than for the 9-cm treatment, corresponding to increases in LAI. Three days after defoliation, CER was negative in both treatments, but rapid LAI development for the taller stubble resulted in a more rapid increase in CER for that treatment. In both species regardless of cutting treatment, as the LAI increased, CER increased also. Similar results were obtained by Leafe and Parsons (1981). They found that canopy photosynthesis in Lolium perenne (L.) decreased markedly as grazing intensity increased.

Plant reserves for regrowth

Another factor affecting pasture regrowth and persistence is plant reserves. The importance of carbohydrate reserves in regrowth after defoliation has been a matter of continuous controversy (Harris, 1978).

Evans, cited by Harris (1978), mentioned that after defoliation, regrowth of grasses and legumes occurs by translocation of labile carbohydrates from stem bases and roots. Langer and Keoghan (1970), cited by Harris (1978), reported that in New Zealand, the role of reserves in recovery of L. perenne (L.) and T. repens (L.) after defoliation is not considered significant, but their role is recognized as an important factor in Medicago sativa (L.).

White (1973) indicated that reserve constituents as nonstructural carbohydrates included reducing sugars (glucose and fructose), non-reducing sugars (sucrose), fructosans, and starch. It is well recognized that reserves in grasses are not only constituted by carbohydrates, but also nitrogenous compounds, although in most species, alcohol-soluble carbohydrates form the largest part of stored reserves (Perry and Moser, 1974; and Smith, 1975).

The predominant reserve constituents of temperate grasses are sucrose and fructosan, and in the case of tropical grasses, sucrose and starch. White (1973) also reported that nitrogenous compounds are used in respiration, but they are not alternately stored and utilized as are carbohydrate reserves. Smith (1975) found that in Panicum virgatum the principal component of total non-structural carbohydrate (TNC) was starch (12%) followed by sucrose (4%) and reducing sugars (1%).

Major storage organs of carbohydrate reserves are usually stem bases, stolons, corms, and rhizomes (White, 1973). In undisturbed plants, reserves accumulate when excess photosynthate is produced (Harris, 1978; Pollock, 1981). Complete defoliation causes brief cessation of root growth, and plant reserves are used as energy sources for respiration and initiation of growth (Davidson and Milthorpe, 1966, cited by Harris, 1978). Respiration requirements and structural components of this new growth are supported by export of reserves from root and stubble until photosynthesis is established at a level that meets requirements for respiration and growth of the plant (Harris, 1978).

The level of accumulated carbohydrates is influenced by several factors. These include seasonal and diurnal fluctuations (Steele et al. 1984; Coyne and Bradford, 1987), species (Langer and Keoghan, 1970, cited by Harris, 1978), temperature (Lym and Messersmith, 1987), water stress, N fertilization, and defoliation (Harris, 1978).

Importance of TNC concentration following defoliation interacts with the amount of photosynthetically active tissue left in the pasture. Ward and Blaser (1961) concluded that in orchardgrass (Dactylis glomerata L.) the rate of regrowth following defoliation was affected by both carbohydrate reserves and the leaf area remaining. Harris (1978) suggested that reserve TNC is important up to a certain point, approximately 2 to 7 d after defoliation in grasses or until one fully-expanded leaf has been formed. White (1973) indicated that the level of carbohydrate reserves in the lower regions of the stems apparently affects the regrowth rate for 2 to 7 d following herbage removal. Following the initial period, plant regrowth depends upon other factors such as leaf area and nutrient uptake. This period of reliance on reserves can be longer in other species like Medicago sativa (L.) which relies on reserves for a period of 21 d.

Harris (1978) concluded that the role of TNC in regrowth and persistence is particularly important where climatic extremes of low temperature and drought seriously retard growth for prolonged periods. Perennials adapted to such environments often have specialized storage tissues. Reduction of reserves by severe defoliation before stress periods is likely to reduce survival and regrowth when favorable conditions return. Booysen and Nelson (1975) indicated that both residual leaf area and reserve carbohydrates contribute energy to regrowth of grasses, and severity of defoliation is thought to affect the dependence of regrowth on stored energy. If defoliations are frequent and severe, relative growth rate and carbohydrate reserves may be reduced and the time intervals for recovery may be too short. Then grazing pressures should be regulated to avoid severe defoliation and to allow sufficient leaf area to be maintained throughout the growing season.

Brown and Blaser (1965), working with *D. glomerata* and *F. arundinacea*, found that TNC in stubble decreased from 320 to 200 g kg^{-1} in *Dactylis* and from 430 to 340 g kg^{-1} in *Festuca* 14 d after defoliation. Plants started to accumulate TNC about 20 d after defoliation. The time required for complete restoration of TNC was 34 d for *Dactylis* and 42 d for *Festuca*. Adjei (1978) studied the effects of stocking rate upon TNC during a grazing cycle of 42 d (14 d grazing, 28 d rest) in *Cynodon* sp., *Digitaria decumbens*, and *Paspalum notatum*. He found that TNC concentration decreased during the first week of rest and then increased, with a 28-d rest period being enough for restoration of TNC present at the beginning of the grazing cycle. Changes over time have been reported for TNC in limpograss stem bases by Adjei et al. (1988). They found that TNC concentration decreased from 55 g kg^{-1} at initiation of grazing to 42 g kg^{-1} at the beginning of the third grazing season, and this reduction was associated with a reduction in plant vigor under prolonged utilization.

Nutritive Value

Mott (1959) suggested that quality of a forage be measured in terms of animal performance. He indicated that output per animal is a function of forage nutritive value, defined as the chemical composition, digestibility, and nature of the digested products of forage by Mott and Moore (1985), and the rate to which forage is consumed by the animal. When determining forage quality, animal potential must not be limiting, forage on offer must exceed intake, and no other sources of supplemental energy or protein can be used. Minson et al. (1976) indicated that the level of animal production from pasture is basically determined by daily intake of net energy, but maximum intake and performance will be achieved only when the diet contains sufficient energy, protein, and minerals.

Mott and Moore (1970) in their forage evaluation scheme, advised the use of laboratory methods when screening plants for agronomic characteristics or when looking at effects of grazing on pastures. Crude protein (CP) and in vitro organic matter digestibility (IVOMD) are useful methods for comparing nutritive value of a large number of samples. These values provide only an estimation of forage quality, so caution must be exercised in making recommendations from these data alone.

Differences in nutritive value between tropical and temperate forages have been pointed out by Moore and Mott, (1973), Minson (1980), Mott (1981), and Minson (1983). It has been accepted that the difference in nutritive value (CP and IVOMD) between tropical and temperate legumes is not as great as between grasses of the two regions. Protein concentration of legumes can be expected to be between 150 and 200 g kg^{-1}, and in some cases the value is even higher (Mott, 1981). Tropical legumes are only slightly less digestible than temperate species with an average difference of about 4% (Minson, 1985).

Another important characteristic of legumes is their slower decrease in nutritive value with maturity than is observed generally with grasses (Milford and Haydock, 1965). Slow reductions in N concentration has been reported in the legumes Greenleaf desmodium and Macroptilium atropurpureum cv. Siratro as age increased (Johansen, 1978 and 1979). Decreases in in vitro digestible organic matter (IVDOM) from 750 to 640 g kg^{-1} have been reported in rhizoma peanut as cutting interval has been increased (Beltranena et al., 1980). Similar results have been reported by Sollenberger et al. (1987b), who found that early initiation of grazing in an association of limpograss and aeschynomene resulted in higher CP and IVOMD in forage, more rapid legume regrowth with higher leaf/stem ratio, and greater IVDOM consumption per hectare by grazing animals.

In the context of grazing management decisions, nutritive value of a forage is an important aspect to be considered when determining the length of the grazing cycle. However, when working with forages whose nutritive value is not greatly affected by maturity, as is the case for some forage legumes, it may be possible to select a grazing management strategy based primarily on the range where maximum pasture productivity and persistence are achieved.

Animal Performance and Pasture Productivity

The effect of including forage legumes in animal diets on animal performance has been documented by several authors (Whiteman, 1980; Mott, 1981; and Kretschmer, 1985). In the region of Los Llanos Orientales in Colombia, Tergas et al. (1983a) reported that beef production on native grasslands was increased 30% with the inclusion of a pure stand of kudzu (Pueraria phaseoloides Roxb.) for complementary grazing. The same author (Tergas et al., 1983b) found that animal productivity on Andropogon gayanus was increased about 40 to 60% by including Stylosanthes capitata or P. phaseoloides. Management required is different, however, than when managing Andropogon alone, and maintenance fertilization is needed after the second year. Lascano and Estrada (1989) reported increases in animal production of

43% for an association of *Brachiaria decumbens* cv. Basilisk with *Pueraria phaseoloides* CIAT 9900 in comparison with *Brachiaria decumbens* alone. This effect was related to higher gains during the dry season on the grass-legume pastures. Mean ADG during the dry season over 9 yr were 0.252 and 0.458 kg animal^{-1} d^{-1} for the grass alone and the grass-legume pastures, respectively.

Cowan and Davison (1982), working with an association of *Neonotonia wightii* cv. Tinaroo and *Panicum maximum* cv. Trichoglume, reported that increasing stocking rate from 1.3 to 2.5 animals ha^{-1} increased milk production linearly from 4950 to 8220 kg ha^{-1}, although milk production per animal decreased linearly from 3810 to 3290 kg. Also, linear reductions in yield of the legume and grass components were observed as stocking rate was increased. Similar results have been reported in Pangola digitgrass by Blunt (1978). Aiken (1989) evaluated an association of bahiagrass, 'Florida' carpon desmodium [*Desmodium heterocarpon* (L.) DC.], aeschynomene, and phasey bean [*Macroptilium lathyroides* (L.) Urb.]. Increases in stocking rate from 2 to 5 animals ha^{-1} during the first grazing season, and 3 to 7 during the second one, resulted in linear declines in herbage mass and ADG, but there was a curvilinear increase in gain per hectare as stocking rate increased.

Cajas et al. (1985) found a reduction in ADG as stocking rate was increased in pastures of Brachiaria humidicola (CIAT 679)-Melinis minutiflora-Desmodium ovalifolium (CIAT 350). Daily gains of 311, 220, and 17 g d^{-1} for the stocking rates of 1.72, 2.30, and 3.23 animals ha^{-1} were reported. Similar tendencies were observed in forage availability.

The effect of rest period on herbage production has been documented by Canudas-Lara (1988) and Santillan (1983). They have reported that the major effect on herbage accumulation was intensity of defoliation and a smaller percentage of the variation was explained by rest period. Different results have been reported by Maraschin et al. (1981) who reported that the contribution of Desmodium intortum to dry matter yield was larger when rest periods were longer.

Rhizoma peanut

Arachis glabrata (Benth.) is indigenous to Argentina, Paraguay, Uruguay, Bolivia, and Brazil (Gregory and Gregory, 1979; Bogdan, 1977). The first species were introduced into the United States in 1936 by W. Archer, as PI 118457 and released to farmers with the variety name 'Arb' (Prine, 1964). In 1962, a different plant was observed in an Arb rhizoma peanut plot by G.M. Prine. He isolated it and tested it as Gainesville selection No. 1 (GS-1) (Prine, 1973). It is suspected that this selection was a seedling from Arb. This rhizoma peanut selection was released in 1979 as 'Florigraze' (Prine et al., 1981a).

Rhizoma peanut is a perennial plant arising from a central branching root. Its primary branches are prostrate or creeping, and often are attached to the ground by adventitious roots. Plants produce short, sub-erect flowering stems at the crown, and leaves are small, glabrous and four-foliate. The leaflets are broadly ovate to elliptic, ranging from 6 to 30 mm long and 5 to 14 mm wide. The flowers are yellow and axillary (Herman, 1954, cited by Skerman, 1977).

Adaptation

The most favorable climatic conditions for peanut are moderate rainfall during the growing season, an abundance of sunshine, temperatures above 16^{o}C for 5 or more months, and never falling below -10^{o}C (Martin et al., 1986). Prine (1981a) indicated that rhizoma peanut grows best under warm, humid conditions, and on well-drained soils of all textures. Established rhizoma peanut can tolerate long periods of drought, but growth is retarded under these conditions. Albrecht et al. (1989) found that prolonged, moderate water deficits resulted only in small decreases in canopy evapotranspiration and photosynthesis, which indicates drought tolerance in this plant. They reported that yield reductions associated with water stress appeared to be due to a combination of decreased photosynthesis and to accumulation of nonstructural carbohydrates in rhizomes at the expense of shoot growth. Similar results were reported by Mansfield and Bennett (1989) who mentioned that except in severe soil water deficits, perennial peanut was only slightly responsive to water management. Reductions in dry matter yield of 18 and 26% for the first and second year were reported for the rain-fed treatment as compared with the well-watered treatment. In both years rhizome TNC increased with increasing water deficits.

Establishment

One of the most important problems limiting rhizoma peanut utilization is its slow rate of establishment (Prine, 1973; Williams, 1973; Adjei and Prine, 1976; Prine et al., 1981; and Canudas-Lara, 1984). As rhizoma peanut usually produces few seeds, it must be propagated from rhizomes (Prine, 1981a). Specific steps for establishing perennial peanut have been reported by Prine (1981a, 1981b, and 1983b), Adjei and Prine (1976).

Soil preparation: Soils should be tested before planting rhizoma peanut, and fertilizer must be applied and incorporated into the soil prior to planting (Prine et al., 1981). If soil test recommendations are not available, 15 kg of P and 56 kg of K per hectare before planting are recommended (Prine et al., 1981a; and Prine, 1983a). A soil pH range of 5.8 to 6.5 appears to be satisfactory for rhizoma peanut (Prine et al., 1981).

Rhizome harvest: Rhizomes are dug by cutting the rhizome mat into ribbons that are 22 to 38 cm wide. This is done using coulters and digging with a modified potato digger. They can also be dug with bermudagrass sprig harvesters that break the rhizomes into shorter pieces which are needed for best growth of new plants and allow mechanized planting with bermudagrass sprig planters (Prine, 1981a).

Planting method and density: Canudas-Lara (1984) found that Florigraze dry matter yield increased linearly with increasing planting rates in a range between 350 and 3800 kg of rhizomes ha^{-1}. Prine et al. (1981) indicated that rhizoma peanut can be planted in hills up to 1.8 m apart using rhizome mats 30 cm^2 or larger. Another possibility is to separate the mat into four pieces and plant in hills 0.9 m apart. The rhizomes must be inoculated and covered to a 6-cm depth if planted in sandy loam or heavy textured soils, and to an 8-cm depth in sands (Prine, 1981a). Using either method, 1 ha of well-established Florigraze can be used to plant 36 ha.

An important problem for rhizoma peanut establishment is that common bermudagrass is often found growing with it. Because both species have extensive rhizome growth, common bermudagrass may be unintentionally planted with rhizoma peanut. Canudas-Lara et al. (1984) indicated that direct application of sethoxydim to the dormant rhizomes of common bermudagrass and rhizoma peanut prior to planting can effectively control the common bermudagrass with no apparent detrimental effect on rhizoma peanut. Canudas-Lara et al. (1989) found that at the end of the first year of establishment, peanut ground cover and dry matter harvested were approximately two times higher when grass and broadleaf weeds were controlled in comparison with the treatment where only broadleaf weeds were controlled.

Some alternatives can be used to overcome the problem of slow establishment in perennial peanut. Valentim et al. (1987) interplanted alfalfa and perennial peanut, trying to combine the best features of each legume. Interplanting resulted in a better yield distribution throughout the years than that observed for each crop in pure stands. Alfalfa accounted for 100 and 95% of the forage harvested in the first and second year after planting. The alfalfa stand declined in the fourth year after planting, however, and rhizoma peanut gradually replaced it.

Establishment costs: The cost of establishing perennial peanut is similar to that of alfalfa and 'Coastal' bermudagrass. The main disadvantage of perennial peanut is that it produces no economic returns for the first 2 yr (Andrews et al., 1985). The largest expense in establishment of perennial peanut is the purchase of 0.7 t (40 bushels) of rhizomes which costs about $100.00. Total establishment cost has been estimated to be \$490 ha^{-1} (Prine, 1984; and Prine et al., 1984).

Dry Matter Production

Dry matter production is affected by various factors such as rainfall, fertilization, and light, and a wide range of values for dry matter production have been reported. Prine (1973), in a study where different varieties of perennial peanut were evaluated, reported that Florigraze had the highest dry matter production with 10.3 Mg ha^{-1} yr^{-1}, as a 4-yr average. In other studies, production levels of 10.5 Mg ha^{-1} yr^{-1} (Prine et al., 1981) and 6.0 Mg ha^{-1} yr^{-1} (Canudas-Lara, 1984) have been reported. Beltranena et al. (1981) reported no differences in yield in the first year of study when rhizoma peanut was harvested at 6, 8, 10, or 12 wk intervals. In the second year of study, maximum production was obtained with the 8-wk cutting interval (12.4 t ha^{-1}). They recommended a frequency for harvests of hay in peninsular Florida of three times a year corresponding to the 8-wk cutting interval. Nitrogen fixation of 100 to 150 kg ha^{-1} yr^{-1} has been reported (Johansen, 1982).

Nutritive Value

Rhizoma peanut is a forage plant with high nutritive value. Crude protein and mineral concentrations are similar to alfalfa, and it is low in crude fiber (Blickensderfer et al., 1964).

Chemical composition of the dry matter (in g kg^{-1}) has been reported to be CP, 177; ether extract, 36; N free extract, 471; crude fiber, 204; and residual minerals, 113 (Otero, 1952). Dunn (1986) mentioned that rhizoma peanut CP concentration is less variable between cuttings than alfalfa.

In other studies, Prine et al. (1981a) reported that the CP concentration was between 122 and 191 g kg^{-1} and IVDOM between 561 and 717 g kg^{-1}. Beltranena et al. (1980) reported decreases in CP and IVDOM from 220 to 150 g kg^{-1}, and 740 to 640 g kg^{-1}, respectively, as cutting interval was increased from 2 to 12 wk.

In a comparative study reported by Baltensperger et al. (1984), digestible energy was not different in rhizoma peanut and alfalfa hays (2.20 to 2.42 Mcal kg^{-1}), and CP was only slightly higher in alfalfa. In a more recent study Romero et al. (1987) reported values of CP for leaves and stems of 270 and 110 g kg^{-1}, respectively. Alfalfa leaves were more degradable in the rumen than peanut, but peanut stems were more degradable than alfalfa stems. The authors mentioned that even though CP of peanut was lower than alfalfa, similar digestibility and slow CP degradability in peanut suggest nearly equal overall nutritive value.

From the practical point of view it has been stated that the nutritive value of peanut hay is comparable to alfalfa with a big difference in price. In Florida, a 30 to 35 kg bale of perennial peanut hay costs $4.00, in comparison with $9.00 per bale of good alfalfa hay (Williams, 1988).

Forage Conservation

Perennial peanut hay has been used successfully in Florida with no major problems (Baltensperger et al., 1984; Staples and Emanuele, 1988). According to Romero et al. (1987), the quality-related characteristics of peanut hay are similar to alfalfa.

Staples and Emanuele (1988) reported acceptable results of making perennial peanut silage in terms of CP (139 g kg^{-1}) and neutral detergent fiber (550 g kg^{-1}, similar to alfalfa hay). These authors also mentioned that when perennial peanut silage was fed to dairy cows at 20 to 35% of the diet, intake of dry matter was 4% of body weight. Optimum dry matter intake was predicted when 15 to 20% peanut silage was offered. In another study, Bates et al. (1989) reported that perennial peanut can be preserved as round bale silage. The most important characteristics influencing round bale silage quality are dry matter at the time of ensiling and maturity. Wilting to increase dry matter at time of ensiling improved dry matter recovery and decreased butyric acid concentration and NH_3 as percentage of total N.

Grazing Studies

Rhizoma peanut produces a very dense mat of underground rhizomes which enables it to tolerate close grazing (Prine, 1973). Under close grazing, rhizoma peanut takes on a prostrate growth habit that makes removal of all top growth by livestock virtually impossible. It has been suggested that overgrazing will probably not eliminate established rhizoma peanut from a grass mixture (Williams, 1973).

Grazing information is limited for rhizoma peanut. A Florigraze-'Pensacola' bahiagrass pasture was closely grazed by cattle for 6 yr, and the peanut stand not only persisted well, but even increased (Prine et al., 1981a).

In a 90-d creep grazing study using suckling Brahman calves, Saldivar et. al. (1981) found that calves grazing perennial peanut were 15 kg heavier at weaning than those with no access to the peanut pasture. Cows on the peanut treatment lost 3.6 kg of body weight in comparison with the cows on the control treatment which lost 22 kg during the experimental period.

In a study by Sollenberger et al. (1989), it was reported that Pensacola bahiagrass carried more animals than rhizoma peanut (1520 vs. 1150 kg liveweight ha^{-1}), but ADG and gain per hectare were higher for peanut (0.93 vs. 0.35 kg, and 342 vs. 216 kg, respectively). Similar results in terms of stocking rate carried have been reported by Grof (1985). He observed in a year-round grazing system of Arachis pintoi in association with four Brachiaria species that pastures were able to carry 2.4 animal units ha^{-1}, with ADG of 515 g animal^{-1} d^{-1} over 594 d of grazing. Mean annual legume percentage in the mixture ranged from 20 to 44.8%. In a continuously-stocked association of Cynodon sp. and Paspalum sp. with Florigraze rhizoma peanut, Williams et al. (1989) reported ADG of 0.68 and 0.89 kg animal^{-1} d^{-1} for the first and the second year of study. A fixed stocking rate of 1.4 steers ha^{-1} was used.

Other Uses

It has been stated that perennial peanut hay can be successfully fed to horses (Equus caballus) as hay or pasture. Acceptance of this new forage by the horse producers has been considered good (Baltensperger et al. 1984; Degner and Locascio, 1988; and Dohn, 1988).

Dehydrated perennial peanut leaf meal has been used with good results as a pigment for laying hens (Gallus domesticus) (Janky et al., 1986). In a feeding trial with rabbits (Oryctolagus cuniculus) conducted by Gomez-de-Varela et al. (1983), feed consumption was higher for alfalfa than for kudzu (Pueraria spp.) and rhizoma peanut, but ADG was similar for rhizoma peanut and alfalfa (39.7 g animal^{-1} day^{-1}). The authors concluded that rhizoma peanut meal has potential to be used in rabbit diets as a suitable replacement for alfalfa meal. Lopez et al. (1988) reported that a sow (Sus scrofa) can maintain acceptable reproductive performance over four successive gestation periods when being fed a diet containing 80% perennial peanut.

Summary

The published literature indicates that rhizoma peanut is a persistent, high quality legume for warm climates. It is well suited for use in numerous livestock enterprises. No data exist, however, to guide grazing management decisions for peanut pastures. The studies that follow were designed to provide such data and to develop recommendations for use of peanut under grazing.

CHAPTER III
EFFECT OF GRAZING MANAGEMENT ON RHIZOMA PEANUT HERBAGE ACCUMULATION AND GRAZING EFFICIENCY

Introduction

Major limitations to high productivity of tropical forage-livestock systems include seasonal availability of forage, low production potential of native plants, minimal legume contribution, and low forage quality. Several alternatives may be considered for improving productivity of these systems. These include use of high yielding legumes and more drought tolerant grasses which improve quality and can extend the grazing season, use of preserved forages for feed during the dry season, and improvement of grazing management strategies to optimize pasture utilization.

Use of legumes may be attractive because of their ability to add symbiotic N to soil and to improve protein concentration of the animal's diet (Mott, 1981; Kretschmer, 1985). Despite their potential, use of legumes in tropical regions is limited. Mott (1981) stated that grass-legume associations in tropical environments have been only moderately successful. Maraschin et al. (1981) concluded that forage legumes have played only a minor role in the tropics primarily due to poor persistence under grazing. Lack of understanding or implementation of proper grazing management has contributed to this problem since use of forage legumes in a grazing system requires more careful management than that needed for a grass monoculture. Knowledge of plant responses to grazing stress is an indispensable tool in planning successful grazing systems, i.e., those in which pasture productivity is sustained at appropriate levels.

An important genus of forage legumes is Arachis, and species like A. pintoi and A. glabrata are being tested in South America, Mexico, and USA. 'Florigraze' rhizoma peanut (Arachis glabrata Benth.) was released to producers in 1979 (Prine et al., 1981). Animal performance trials conducted by Sollenberger et al. (1989) have demonstrated good productivity of Florigraze under grazing and exceptional steer (Bos spp.) gains (0.93 kg head^{-1} d^{-1}). Knowledge of peanut responses to a range of grazing management strategies is needed by producers to obtain the greatest benefit from its use in pastures. No data are available that would enable grazing management decisions to be made with an understanding of their potential effect on level and consistency of peanut productivity.

For these reasons a plant response to grazing stress study was conducted. Objectives were to a) determine the effect of postgraze residual dry matter (RDM) and length of grazing cycle (GC) on total and peanut herbage accumulation (HA), and grazing efficiency, and b) define the range of grazing management under which rhizoma peanut pasture productivity is maximized.

Materials and Methods

Site conditions

This study was conducted in 1988 and 1989 at the Forage Evaluation Field Laboratory of the University of Florida's Beef Research Unit. A well-established, 1-ha pasture of rhizoma peanut was used. The predominant soil series at the experimental site is Sparr fine sand (loamy, siliceous, hyperthermic Grossarenic Paleudults). Mean soil pH and Mehlich I extractable (mg kg^{-1}) P, K, Mg, and Ca at the beginning of each year were 6.7, and 24, 36, 108, and 516, respectively, in 1988, and 6.7 and 32, 44, 80, and 476 in 1989. Phosphorus and K were broadcast applied in April each year at rates of 25 and 92 kg ha^{-1}, respectively. Twenty two kilograms per hectare of a micronutrient mixture (F-503 Oxide) were applied with the P and K. Rainfall patterns varied in the 2 yr (Table 1). In 1988, January through March were very wet, but the period of April through July was dry. In 1989, the situation was nearly the reverse of that in 1988.

Table 1. Monthly rainfall totals (mm) at the Beef Research Unit, Northeast of Gainesville, Florida, and 30-yr means for Gainesville.

Month	Year		30-yr mean
	1988	1989	
January	119	24	82
February	120	31	98
March	192	47	92
April	26	100	73
May	52	59	105
June	56	256	164
July	59	448	173
August	350	60	201
September	241	120	141
October	23	30	59
November	95	47	51
December	31	94	81
Total	1364	1316	1320

Experimental variables and design

Treatments included all combinations of three levels of RDM (500, 1500, and 2500 kg ha^{-1}) with four levels of GC (7, 21, 42, and 63 d). Grazing cycle was defined as days of grazing (2 d or less) plus days in rest period between grazings. Residual dry matter was total live herbage to ground level at the end of a grazing period. The 12 treatments were randomly assigned to 400-m^2 pastures within each of two blocks in a randomized complete block design. Because of the size of the pastures, it was not possible to maintain cattle on continuously stocked treatments during the complete grazing season. Thus, continuous grazing was simulated by grazing approximately every 7 d (GC=7) to maintain RDM at the target level.

Steers of an average liveweight of 400 kg were used as grazers to achieve the RDM target specific for each treatment. Animals were put on pastures following pregraze sampling. Number of steers needed to achieve the RDM target in a period no longer than 2 d was estimated. During the grazing period the number of animals was adjusted if it was expected that the target RDM would not be achieved in that amount of time.

Sampling procedure

Pastures were sampled before and after grazing using a double sampling technique to determine herbage mass and botanical composition of the pasture. Four double samples (visual estimation of herbage mass and botanical composition, followed by clipping to ground level at four selected, representative sites) and 15 visual estimations (randomly selected sites) were taken in each pasture. Samples from the four, 0.25-m^2 sites were hand-separated and dried at 60°C to obtain the actual dry weight of peanut, grass, and weeds. Four 1-m^2 exclusion cages were placed on continuous grazing treatments to estimate HA. Herbage from 0.25-m^2 areas inside cages and four 0.25-m^2 areas outside cages were clipped every 21 d. Cages were then moved to new sites.

Actual values for total herbage mass and percentage of each component (peanut, grass, and weed) were regressed on visual estimations of the responses from double sampling sites to generate prediction equations. Means of the 15 visual estimations taken per paddock and the prediction equations (Table 2) generated from double sampling were used to predict pasture values for herbage mass and percentages of peanut, grass, and weeds.

Response variables

Response variables calculated included total and component HA, and grazing efficiency. Herbage accumulation for a given GC is the difference between herbage mass after grazing of the previous GC and herbage mass before grazing of the current GC. Herbage accumulation for the first GC is

Table 2. Regression equations relating actual values from clipped samples to visual estimates taken at the same sites.

Response variable	1988	1989
Herbage mass before grazing	y†$=62+1.03\ x$‡ SEyE§$=609$ r^2¶$=0.87$ $n=518$	$y=559+0.91\ x$ $SEyE=522$ $r^2=0.90$ $n=389$
Peanut percentage before grazing	$y=-4+1.022\ x$ $SEyE=8.5$ $r^2=0.80$ $n=558$	$y=1.28+0.94\ x$ $SEyE=15.5$ $r^2=0.77$ $n=389$
Grass percentage before grazing	$y=2.1+1\ x$ $SEyE=8.5$ $r^2=0.80$ $n=558$	$y=4.9+0.93\ x$ $SEyE=15.6$ $r^2=0.78$ $n=389$
Herbage mass after grazing	$y=45+1.04\ x$ $SEyE=531$ $r^2=0.80$ $n=294$	$y=-33+0.99\ x$ $SEyE=349$ $r^2=0.89$ $n=211$
Peanut percentage after grazing	$y=4.2+0.93\ x$ $SEyE=7.3$ $r^2=0.80$ $n=354$	$y=1.1+0.92\ x$ $SEyE=18$ $r^2=0.69$ $n=211$
Grass percentage after grazing	$y=3.09+0.98\ x$ $SEyE=8.4$ $r^2=0.80$ $n=362$	$y=6.4+0.77\ x$ $SEyE=17$ $r^2=0.69$ $n=211$

†y=adjusted (actual) value of the response variable.
‡x=mean of 15 visual estimates of the response variable.
§SEyE=Standard error of y estimate.
¶r^2=coefficient of determination.

simply pregraze herbage mass. These data were summed over cycles to provide seasonal totals. For continuous grazing treatments, HA for a given 21-d period was the difference between herbage mass outside cages at the beginning of that period and herbage mass inside cages at the end.

Grazing efficiency is the percentage of total-season HA that was consumed by grazing animals. For rotational grazing treatments, herbage consumption (HC) was calculated by subtracting herbage mass after grazing from herbage mass before grazing in the same cycle. In the case of continuous grazing, this response was the difference between herbage mass outside cages at the end of the 21-d period and herbage mass inside cages at the same time. Data were summed over the season in all cases. Herbage accumulation and grazing efficiency for the botanical components were calculated using the same approach as for total herbage.

Statistical analysis

Response variables were analyzed statistically using the least squares method of the GLM procedure of the SAS Institute Inc. (1987). Data are reported by year because interactions with year were numerous. The complete model used was a second order polynomial response surface. Only those effects in the complete model which explained a significant ($P \le 0.10$) portion of the variation in the response were included in the reduced model. For several response variables an effect for which $P \le 0.10$ in the complete model had P>0.10 in the reduced model. These effects were included in the equation, nonetheless. The P value reported in the text is that for the reduced model. When there was a GC by RDM interaction, the linear effects of both terms were included in the model independent of their level of probability. Similarly, when there was a quadratic effect, the linear effect was included. In cases where P>0.10 in the reduced model, the P value for that effect in the complete model is listed in a footnote in the appropriate appendix table. The complete model is written as follows:

$$y=\beta_0 + \beta_1GC + \beta_2GC^2 + \beta_3RDM + \beta_4RDM^2 + \beta_5GC*RDM + \epsilon$$

where, y is the estimated response variable,
RDM is the residual dry matter,
GC is the grazing cycle,
β_0 is the intercept,
β_1 and β_3 are the linear coefficients for GC and RDM, respectively,
β_2 and β_4 are the quadratic coefficients for GC and RDM, respectively,
β_5 is the cross-product coefficient for GC and RDM, and
ϵ is the experimental error.

The actual RDM obtained varied from target levels since it was not possible to visually estimate the exact time when cattle should be removed. Thus, actual RDM values were used in the regression analysis. Mean actual RDM over the 2 yr, however, did not vary from target RDM by more than 100 kg ha^{-1} for any of the treatments.

The graphs were plotted with Surfer 4.07 software from Golden Software Inc. (1989) and Sigmaplot (1989). Contour plots are presented for ease of interpretation and identification of zones of maximum response. For two response variables, both surface and contour plots are included for illustration purposes.

Results and Discussion

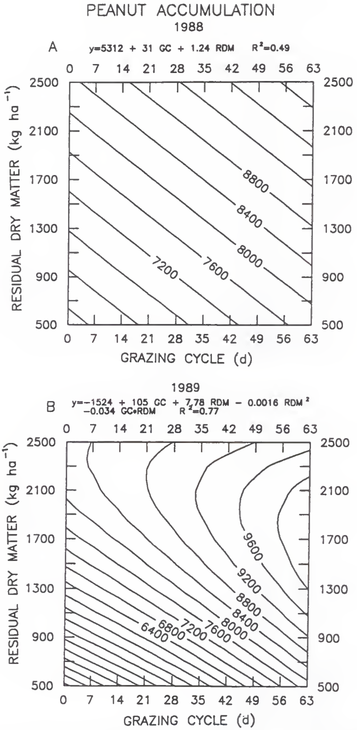
Herbage Accumulation

Total herbage accumulation

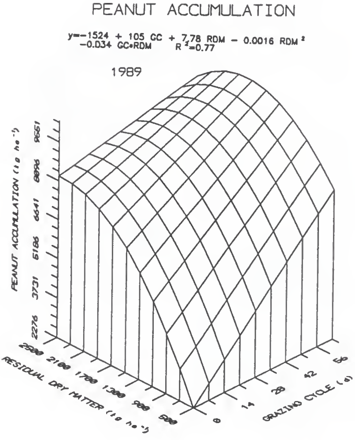
There was no effect of the experimental variables on total HA in either year. As peanut HA varied due to treatment, grass HA varied in an inverse manner.

Peanut herbage accumulation

For the first grazing season, peanut HA increased linearly as GC ($P=0.02$) and RDM ($P<0.01$) increased (Fig. 3.1A; Table A-1). The range of peanut HA was from 6150 to 10370 kg ha^{-1}. In 1989, there was a GC by RDM interaction ($P=0.05$) (Fig. 3.1B and 3.2; Table A-2). The effect of GC



3.1. Peanut herbage accumulation (kg ha^{-1}) in A) 1988 and B) 1989 as affected by length of grazing cycle and postgraze residual dry matter.



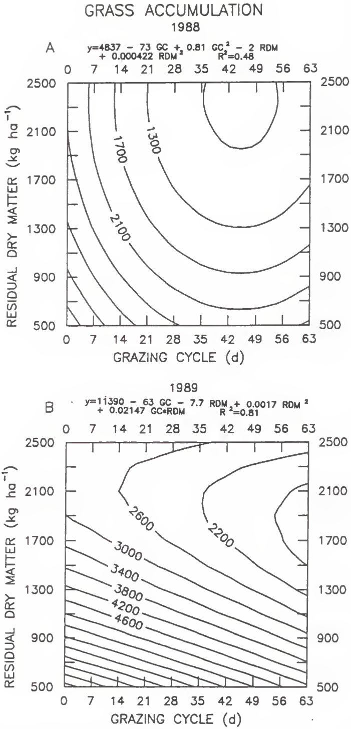
3.2. Surface plot of 1989 peanut herbage accumulation as affected by length of grazing cycle and postgraze residual dry matter.

was most marked when the level of RDM was low, and became less important as RDM increased. The model for 1989 also included the linear effects of GC and RDM ($P<0.01$), and the quadratic ($P=0.02$) effect of RDM. Peanut accumulation in 1989 ranged from 1730 to 9810 kg ha^{-1}, and lowest values, as in 1988, were obtained with short GC and low RDM. Most peanut accumulation in 1988 occurred during the beginning of the grazing season when the effect of treatments was not yet manifested, and that is why the range in that year was smaller than that in 1989.

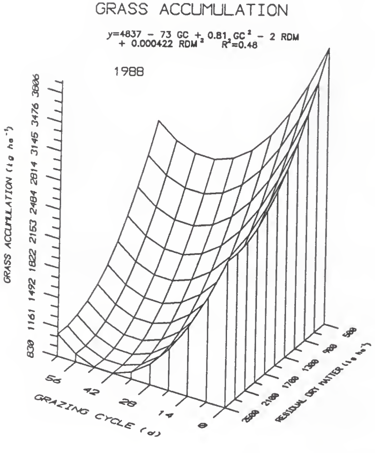
The highest percentage of variation in peanut HA was explained by RDM (40 and 55% for 1988 and 1989, respectively). Similar results were reported by Santillan (1983) and Canudas-Lara (1988). They indicated that the major factor affecting legume HA was intensity of defoliation. Cowan and Davison (1982), working with an association of glycine [Neonotonia wightii (R. Grah. ex Wightii and Arn.) Lackey] cv. Tinaroo and guineagrass (Panicum maximum Jacq.) cv. Trichoglume, found that increasing stocking rate from 1.3 to 2.5 animals ha^{-1} decreased legume yield linearly. Jones (1979) studied the effect of intensity and frequency of defoliation on a siratro [Macroptilium atropurpureum (Benth.)] Urb.-setaria (Setaria anceps Stapf ex Massey) sward. Five stocking rates, ranging from 0.8 to 2.8 steers ha^{-1} and three grazing frequencies of 3, 6, and 9 wk were evaluated. With the 3-wk grazing frequency, siratro and total herbage yield declined markedly as stocking rate increased. The decline in siratro yield with increased stocking rate was less marked with the 9-wk grazing frequency. For Desmodium intortum (Mill.) Urb., Jones (1973) concluded that long intervals between even heavy grazings should enable this legume to attain high yield and compete with associated species. Our data suggest that close defoliation of peanut (RDM of 500 kg ha^{-1}) will reduce legume contribution, regardless of length of GC.

Grass accumulation

Minimum values of grass HA were found with RDM higher than 1500 kg ha^{-1} and GC longer than 21-d in the first year. Included in the model were the linear and quadratic effects of GC ($P=0.05$ and $P=0.11$) and the linear and quadratic effects of RDM ($P=0.04$ and $P=0.14$) (Figs. 3.3A and 3.4; Table A-3). For 1989, there was an interaction between GC and RDM ($P=0.01$) (Fig. 3.3B; Table A-4). Grass contribution was most influenced by GC when RDM was less than 1500 kg ha^{-1}, and above that level GC had little effect on grass HA. The model for 1989 also included the linear effect of RDM ($P<0.01$) and GC ($P=0.01$), and the quadratic effect of RDM ($P<0.01$). This response is similar to that observed by Jones (1979) who evaluated the effect of five stocking rates and three frequencies of grazing on a Macroptilium atropurpureum-Setaria anceps pasture. He found an increase in the contribution of grass with higher stocking rates, but



3.3. Grass herbage accumulation (kg ha^{-1}) in A) 1988 and B) 1989 as affected by length of grazing cycle and postgraze residual dry matter.



3.4. Surface plot for 1988 grass herbage accumulation as affected by length of grazing cycle and postgraze residual dry matter.

the increase was less marked with less frequent grazing.

Grass accumulation in 1989 ranged from 1630 to 8710 kg ha^{-1}. Herbage accumulation above 8000 kg ha^{-1} is high for common bermudagrass. It may be important to note that peanut contribution decreased dramatically during the study for pastures with highest grass yields. This was true for both peanut HA and for peanut rhizome mass. At the beginning of the grazing trial in May 1988, there was an average rhizome mass of 3700 kg ha^{-1}, while at the end of the trial in November 1989, rhizome mass for treatments that had highest grass HA was only 280 kg ha^{-1}. This means that approximately 3400 kg of rhizomes ha^{-1} decomposed and nutrients were likely made available. With peanut rhizome N concentration of approximately 15 g kg^{-1}, a total of 50 kg of N may have been contributed to the soil. Therefore, high productivity of bermudagrass achieved under treatments of low RDM and short GC, may have been due, at least in part, to the N released from peanut rhizome decomposition. Tothill and Jones (1977) observed that good legume growth in one year led to more vigorous grass growth in the next year due to the nutrients released in autumn and winter from siratro leaf litter.

Broadleaf weed accumulation

There was no effect of the experimental variables on this response. Values for broadleaf weed HA never exceeded 240 kg ha^{-1}.

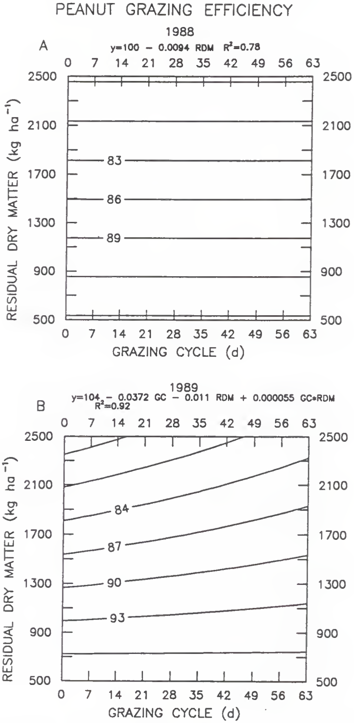
Grazing Efficiency

Total grazing efficiency

For both years of study, grazing efficiency increased linearly ($P<0.01$) from 75 to 95%, as RDM decreased (Tables A-5 and A-6). Thus highest values of grazing efficiency were found with RDM of 500, independent of GC. Grazing efficiency in this experiment can be considered high in comparison with those of Okamoto et al. (1989) who reported values of approximately 60% in a 2-yr study with dairy heifers grazing orchardgrass (*Dactylis glomerata* L.) pastures. Their data were likely calculated on basis of herbage mass, not HA, which could account for the large differences between studies.

Peanut grazing efficiency

For the first grazing season the model included only the linear ($P<0.01$) effect of RDM (Fig. 3.5A; Table A-7). Peanut grazing efficiency ranged from 74 to 97%. For the second grazing season the response ranged from 75 to 98%, and there was an interaction ($P=0.08$) of GC and RDM. The general nature of the RDM response did not vary with GC, but the magnitude of the increase in grazing efficiency with decreasing RDM was greater with long GC (Fig. 3.5B; Table A-8). Model for peanut grazing efficiency also included



3.5. Peanut grazing efficiency (%) in A) 1988 and B) 1989 as affected by length of grazing cycle and postgraze residual dry matter.

the linear effects of GC ($P=0.47$) and RDM ($P<0.01$). The greatest proportion of the variation was explained by RDM (87%). Peanut grazing efficiency ranged generally between 80 and 90% when RDM was higher than 1500 kg ha^{-1}.

Grass grazing efficiency

Grass grazing efficiency for 1988 decreased quadratically as GC ($P<0.01$) increased, and linearly as RDM ($P<0.01$) increased (Table A-9). The range for this response variable was from 61 to 92%. For 1989, the only term included in the model was the linear effect of RDM ($P<0.01$) (Table A-10). The range for the second grazing season was from 67 to 96%. Most of the variation in this response variable was explained by RDM (54 and 72% for 1988 and 1989). In both years, highest values of grass grazing efficiency were found with low RDM, independent of GC.

Conclusions

For HA the range of response was much narrower in the first than in the second year of study. This occurred because most peanut growth occurs in the first few months of the grazing season, and in 1988 the effect of the grazing management treatments was not manifested fully during this period. As a result, general tendencies for response variables studied were similar in the first and second grazing seasons, but the effect of the experimental variables was more marked during the second year (1989).

Maximum levels of peanut HA were similar in 1988 and 1989 and were found in nearly the same range of management in both years. Treatments that imposed greater stress resulted in declining peanut productivity over time, so in 1988 HA was much higher than in 1989. Grass HA showed inverse tendency to peanut HA. As peanut HA decreased, grass HA increased accordingly. This trend may not continue indefinitely, however, because decaying legume residues likely supported high grass yields, particularly in the second year.

Residual dry matter was the most important factor affecting peanut productivity although GC was included in the model for most of the response variables. Maximum level for peanut HA was obtained with an RDM of 1100 to 2400 kg ha^{-1}, which corresponds to a postgraze stubble height of 15 to 22 cm, with a GC longer than 42 d. These data confirm that rhizoma peanut is productive over a relatively wide range of management practices. They indicate however, that close grazing of peanut pastures, particularly in association with short GC, dramatically reduces peanut performance. This type of management should be avoided in systems where sustained high levels of productivity are a high priority.

CHAPTER IV
GRAZING MANAGEMENT EFFECTS ON PERSISTENCE OF RHIZOMA PEANUT

Introduction

Nitrogen deficiency is a major limitation to pasture productivity. Use of N fertilizers is not practical in many cases in tropical regions because of their cost and limited availability. Forage legumes, therefore, provide a potentially valuable resource, but poor legume persistence under grazing has limited the use of these plants in subtropical and tropical environments (Kretschmer, 1989; Pitman et al., 1986 and 1988; and Maraschin et al., 1981). Research aimed at development of sustainable legume-based grazing systems is needed.

Definitions of persistence may address only the presence of a species over time or may also imply certain levels of productivity. Sheat and Hay (1989) propose that the contribution of legume to a forage source is dependent upon the number of growth units (e.g., plants, stolon segments) and their size. Gramshaw et al. (1989) indicate that persistence and adequate yield are both needed if a legume is expected to contribute significantly in the production system. They suggest that "...the definition of persistence is therefore taken to be a 'productive persistence'." If a legume is to contribute meaningfully to both N availability for plant growth and N in cattle diets, productive persistence is required.

Defoliation effects on legume persistence are dependent upon growth characteristics of the particular species and those of associated plants. Defoliation can be characterized by its intensity, frequency, and timing, and each of these attributes can have a major impact on competitive relationships in pasture ecosystems (Harris, 1978). As demonstrated by Jones (1979) with 'Siratro' (Macroptilium atropurpureum (D.C.) Urb., intensity and frequency of defoliation often interact. Understanding this interaction and implementing appropriate grazing management strategies may be keys to developing more persistent legume pastures in warm climates.

This study was conducted to a) evaluate the effect of grazing intensity (postgraze residual dry matter; RDM), grazing frequency (length of grazing cycle; GC), and their interaction on persistence of rhizoma peanut (Arachis glabrata Benth.) pastures, and b) identify a range of grazing management treatments under which rhizoma peanut is likely to persist.

Materials and Methods

This study was conducted in 1988 and 1989 at the Forage Evaluation Field Laboratory of the Beef Research Unit, near Gainesville, Florida. Site characteristics, rhizoma peanut pasture layout, and grazing procedure were described in Chapter III. Experimental variables were GC (7, 21, 42, and 63 d) and RDM (500, 1500, and 2500 kg ha^{-1}). All combinations of the levels of these factors (12 treatments) were arranged as a complete factorial in two replications of a randomized block design. Data were analyzed using least squares method of the GLM procedure of the SAS Institute Inc. (1987), and the complete model used was a second order polynomial.

Sampling Procedure

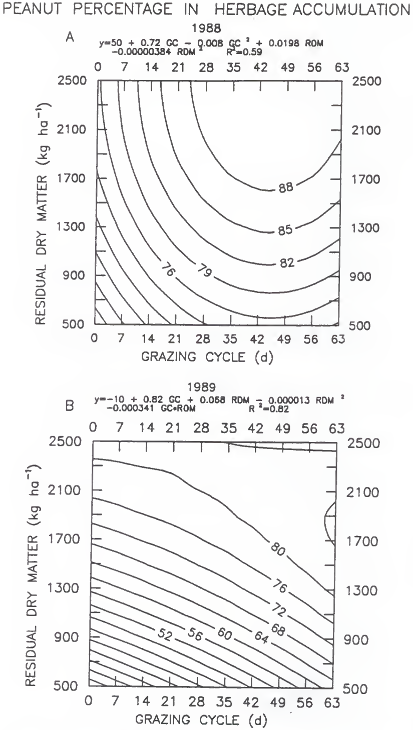
A double sampling technique described in Chapter III was used to determine botanical composition of pastures. Component (peanut, grass, and weed) percentages in total herbage accumulation (HA) were calculated on an annual basis by summing component HA over grazing cycles and dividing by total HA. Percentage peanut in pregraze herbage mass (HM; all live herbage to ground level) is also reported for the first and last grazing cycle of each season.

Results and Discussion

Peanut percentage in herbage accumulation

In 1988, peanut percentage in HA ranged from 61 to 90%. The model included linear and quadratic effects of GC ($P=0.03$ and $P=0.07$) and RDM ($P=0.02$ and $P=0.12$) (Fig. 4.1A; Table A-11). For 1989, the model for peanut percentage in HA included the linear ($P<0.01$) effect of GC, linear ($P<0.01$) and quadratic ($P=0.01$) effects of RDM, and the interaction of GC and RDM ($P=0.01$) (Fig. 4.1B; Table A-12). The interaction occurred because when GC was short, peanut percentage increased as RDM increased over the entire range of RDM. For GC of 42 d or longer, peanut percentage increased very little above an RDM of 1500 kg ha^{-1}. Range for peanut percentage in HA in 1989 was 17 to 85%. Lowest values were found both years with low RDM and short GC, which would be equivalent to a high stocking rate with short rest periods.

These results agree with Whiteman (1969) who reported that important factors affecting legume persistence include height of defoliation and the morphology of the species. Close defoliation tends to remove the major portion of the young active leaf material and terminal meristems, which leads to a reduction in rate of recovery and ability to compete with grasses. Jones (1979) reported that in an association of Nandi setaria (*Setaria anceps* Stapf ex



4.1. Peanut percentage in total herbage accumulation in a) 1988 and b) 1989 as affected by length of grazing cycle and postgraze residual dry matter.

Massey) and siratro (Macroptilium atropurpureum DC. Urb.), the percentage of siratro in total biomass dropped sharply at the highest stocking rate, and there was a corresponding sharp drop in the slope of live weight gain per animal.

There is a shortage of information in the current literature about measurements of herbage accumulation and its botanical composition. In most articles published, herbage mass and its botanical composition are reported for different times during the grazing trial. Although these measurements can be used to describe changes in botanical composition of pastures or persistence of a component, they fail to illustrate the contribution of the component to the total biomass. In other words they fail to give a good idea about "productive persistence".

Grass Percentage in Herbage Accumulation

Models for both years were similar to those obtained for peanut percentage in HA. For 1988, the model included the linear (P=0.04) and quadratic effects of GC (P=0.10) and RDM (P=0.02 and P=0.10, respectively) (Table A-13). Grass percentage in HA ranged from 9 to 39%. For 1989, there was a GC by RDM interaction (P=0.01). When GC was short, grass percentage increased at an increasing rate as RDM decreased. When GC was 42 d or longer, grass percentage remained relatively constant when RDM was above 1500 kg ha^{-1}. The model for grass percentage in HA also included the quadratic effect of RDM (P=0.01) and the linear effects of RDM and GC (P<0.01) (Table A-14). The most important experimental factor affecting grass percentage in HA was RDM. It explained 65% of the variation in the response. Lower values of grass percentage in HA were obtained in the region where maximum values of peanut percentage were found. Common bermudagrass [*Cynodon dactylon* (L.) Pers.] was the main grass species, and it was able to compete effectively with rhizoma peanut under conditions of high grazing stress (low RDM and short GC).

Broadleaf Weed Percentage in Herbage Accumulation

Weed percentage was not affected by the experimental variables in either year of study. In the second year higher values of weed percentage in HA were found than in the first year, but they were always lower than 3%.

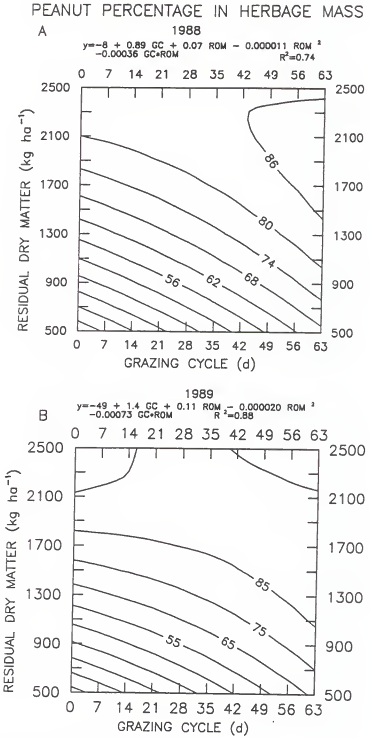
Botanical Composition of Herbage Mass During the Trial

At the beginning of the grazing trial in May 1988, the botanical composition of pastures averaged 90% rhizoma peanut, 10% bermudagrass, and no broadleaf weeds were present. During the first and second grazing seasons large changes in botanical composition were observed only in treatments with low RDM, independent of GC.

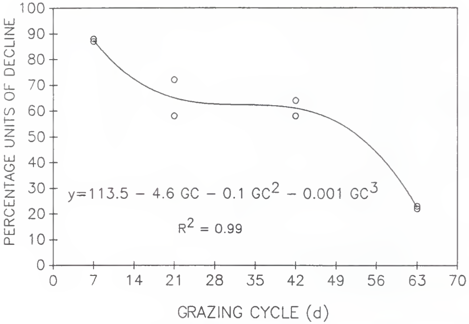
Peanut Percentage in Herbage Mass

In 1988 and 1989, there was a GC by RDM interaction (P=0.02 and P<0.01, respectively) for peanut percentage in HM before the last grazing of the season. Each year the effect of GC was most important at low levels of RDM, but was relatively unimportant if RDM was higher than 1500 kg ha^{-1}. The linear effects ($P<0.01$) of RDM and GC and the quadratic effect ($P=0.02$ and $P<0.01$ for 1988 and 1989, respectively) of RDM were also included in the model (Fig. 4.2A, and 4.2B; Table A-15 and A-16). Lowest peanut percentage occurred with low RDM and short GC.

The range of this response variable was 33 to 88% at the end of the 1988 grazing season, and 9 to 90% at the end of 1989. During the study, dramatic changes in botanical composition occurred only in treatments with RDM of 500 kg ha^{-1}. Percentage units of change in peanut botanical composition from the beginning to the end of the study decreased cubically ($P<0.01$) as GC increased (Fig. 4.3). Rate of change in peanut percentage for simulated continuous grazing (GC=7) was from 90 to 33% in 1988, and from 33 to 9% in 1989. Treatments with the lowest RDM and GC of 21 and 42 d responded similarly, and peanut percentage in HM decreased from 90 to about 50% in 1988, and from 50 to 27% in 1989. The treatment with 500 kg ha^{-1} of RDM and GC of 63 d showed a decrease in peanut percentage in HM from 90 to 60% in the first year, and this value was stable between 60 and 68% during the rest of the trial. Decreases in peanut percentage in HM were compensated for by invasion of common bermudagrass which was greatest for short GC and low RDM treatments.



4.2. Peanut percentage in pregraze herbage mass at the end of the a) 1988 and b) 1989 grazing seasons as affected by length of grazing cycle and postgraze residual dry matter.

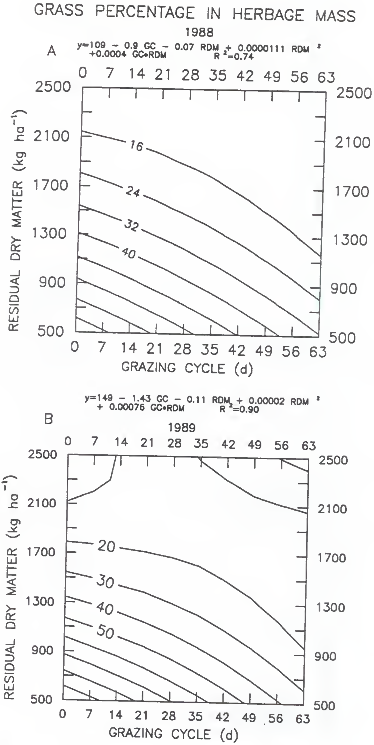


4.3. Percentage units decline in peanut percentage in herbage mass from beginning to end of the study for pastures with an RDM of 500 kg ha^{-1}.

Effects of defoliation intensity and rest period on persistence have been discussed previously (Vickery, 1980; and Sollenberger and Chambliss, 1989). Successful grazing systems have to combine appropriate levels of both. With some species and within a certain range, these two factors can be adjusted inversely without affecting pasture productivity and persistence. Canudas-Lara (1988) reported that highest values of percentage glycine [Neonotonia wightii (R. Grah. ex Wightii and Arn.) Lackey] were found with long GC and high RDM, and glycine disappeared under continuous grazing with low RDM. Similar results have been reported by Jones (1979) in an experiment to evaluate the effect of five stocking rates and three frequencies of grazing on a siratro-setaria (Setaria anceps Stapf ex Massey) pasture. There was a decrease in legume with higher stocking rate, but, as observed in the current study, the decline was less marked with the less frequent grazing. Cowan et al. (1975) evaluated four stocking rates on a green panic (Panicum maximum Jacq.)-glycine pasture. Legume percentage decreased linearly ($P<0.05$) with increasing stocking rates. Different results have been reported, however, by Santillan (1983) working with an association of glycine, centro (Centrocema pubescens Benth.), guineagrass, and elephantgrass (Pennisetum purpureum Schumach.). He found that short rest periods favored legume percentage. This response occurred because guineagrass and elephantgrass are tall growing, and the legumes were favored by short GC that allowed them to compete more effectively for light with grasses. Similarly, Abramides et al. (1983) reported that in a setaria (Setaria anceps Stapf ex Massey)-galactia (Galactia striata Jack. Urb.) association there was a linear reduction in legume percentage as the rest period increased. In the current study, grass and legume had a similar growth habit. Hence competition for light was not as critical, and the amount of photosynthetically active tissue left on pastures after grazing to initiate regrowth seemed to be most important.

Grass Percentage on Pastures

The response of grass percentage in HM at the end of the grazing season was inverse to that for peanut and terms included in the model were the same for both. These included the linear effect ($P<0.01$) of GC, the linear ($P<0.01$) and quadratic ($P<0.02$) effects of RDM, and the interaction of GC and RDM ($P<0.02$) (Figs. 4.4A and 4.4B; Table A-17 and A-18). Similar to the responses for peanut, greatest effects of GC on botanical composition occurred at low levels of RDM. Lowest values for grass percentage in HM were found with long GC and high RDM, i.e., in the range where maximum values for peanut percentage in HM were obtained. Grass percentage on pastures ranged from 11 to 67% and 6 to 97% for 1988 and 1989, respectively. Dominance



4.4. Grass percentage in pregraze herbage mass at the end of the a) 1988 and b) 1989 grazing seasons as affected by length of grazing cycle and postgraze residual dry matter.

of grasses on mixed swards under conditions of high grazing stress has been documented by several authors. Whiteman (1975) suggested that where N and other nutrition is adequate, their potential rate of CO_2 fixation and dry matter production gives tropical grasses a marked competitive advantage over associated legumes. Maintenance of a legume in a tropical pasture sward is usually achieved through a N limitation to potential grass productivity or by grazing management that favors the legume.

Conclusion

Most response variables discussed in this chapter had similar terms included in the model (linear effects of GC and RDM, quadratic effect of RDM, and the interaction of GC and RDM). Most of the variation in botanical composition of HA and of HM at season's end was explained by RDM. In all cases, when peanut stands were depleted there was a substitution of grass for peanut. Broadleaf weeds did not contribute significantly to HA.

The effect of length of GC on peanut percentage was most important at low levels of RDM, but it had little effect when RDM was 2000 kg ha^{-1} or higher. With an RDM of 500 kg ha^{-1} and GC of 7 d, peanut percentage declined from 90 to 9% over the course of the study. At the same RDM with a GC of 63 d, peanut percentage in pastures decreased from

90 to 60% in 1988, and then stabilized between 60 and 68% for the rest of the trial.

Peanut was the dominant component in HA and in HM when the level of RDM was higher than 1500 kg ha^{-1}, independent of GC. This was also true with an RDM of 500 kg ha^{-1} if GC was 63 d, however, doubts exist about the persistence of the stand for periods longer than 2 yr when it is grazed this intensively. To maintain a peanut percentage of 80% or greater, however, these data suggest that RDM should be approximately 1500 kg ha^{-1} or higher, if GC is longer than 42 d, or higher than 2000 kg ha^{-1} if GC is shorter than 35 d. At 2000 kg ha^{-1} of RDM, the length of GC chosen appears to have little influence on peanut persistence.

CHAPTER V
PHYSIOLOGICAL RESPONSES OF RHIZOMA PEANUT TO GRAZING MANAGEMENT

Introduction

Gomide (1981) indicated that forage plants differ considerably in their ability to recover from grazing. He suggested that factors determining regrowth of forage are a) shoot apex survival, b) residual leaf area, c) carbohydrate reserves, and d) tillering potential.

Vickery (1980) mentioned that the relationship between leaf area, light interception, and subsequent growth in terrestrial plant communities is very important because the primary synthesis of dry matter results from the photosynthetic activities of the leaves. Grazing intensity determines in large part the amount of photosynthetically active tissue available to intercept light for photosynthesis and subsequent growth.

The role of carbohydrate reserves in regrowth after defoliation has been a matter of continuous controversy (Harris, 1978). Importance of total non-structural carbohydrate (TNC) concentration in storage organs following defoliation depends to a great extent on the amount of photosynthetically active tissue left in the pasture. Ward and Blaser (1961) concluded that in orchardgrass (Dactylis glomerata L.), rate of regrowth following defoliation was affected by both carbohydrate reserves and leaf area remaining. Harris (1978) suggested that reserve TNC is important up to a certain point following defoliation, approximately 2 to 7 d in grasses or until one fully-expanded leaf has been formed. This period can be longer in other species like alfalfa (Medicago sativa L.), which may use reserves for regrowth for a period of 21 d. Major storage organs for carbohydrate reserves are usually stem bases, stolons, corms, and rhizomes (White, 1973). In this context, evaluation of plant reserves may be approached by quantifying concentration of specific compounds as well as the biomass of storage organs.

Rhizoma peanut possesses a dense mat of rhizomes where plant reserves are stored. In a clipping study, Mansfield (1989) reported that rhizome mass constituted two thirds of total biomass (above and below ground) at any given harvest cycle, and in the last harvest it constituted approximately 85% of total biomass. This is an important characteristic contributing to the persistence of rhizoma peanut under grazing.

Plant reserves for regrowth must be considered when evaluating and designing grazing systems, since above-ground biomass production may be sustained for a relatively long period of time at the expense of plant reserves. Once reserves are depleted severely, however, the pasture may fail to achieve optimum levels of productivity and persistence.

Objectives of this experiment were to a) determine the effect of postgraze residual dry matter (RDM) and length of grazing cycle (GC) on canopy light interception before and after grazing, peanut rhizome mass, and TNC and N concentration in peanut rhizomes, and b) define the range of grazing management under which peanut rhizome mass and plant reserves can be maintained at a level where pasture persistence and productivity are not negatively affected.

Materials and Methods

This study was conducted in 1988 and 1989 at the Forage Evaluation Field Laboratory of the University of Florida's Beef Research Unit. Treatments included all combinations of three levels of RDM (500, 1500, and 2500 kg ha^{-1}) with four levels of GC (7, 21, 42, and 63 d). The 12 treatments were randomly assigned to 400-m^2 paddocks within each of two blocks in a randomized complete block design. Data were analyzed using least squares method of the GLM procedure of the SAS Institute Inc. (1987), and the complete model used was a second order polynomial. Rhizoma peanut pasture layout as well as details regarding experimental variables and design, grazing procedure, and statistical analysis were described in Chapter III.

Sampling Procedure

Light interception was measured after grazing, and every week during the rest period until pasture canopies intercepted 90% of photosynthetically active radiation. In the case of simulated continuous-grazing (GC=7) treatments, light interception was measured each week during the 2 yr of study. Eight measurements of incident light and light penetrating to the soil surface were taken per pasture at randomly selected sites, and light interception was calculated.

Rhizome mass was measured every 21 d during the two grazing seasons. Five core samples of 128 cm^2 were taken to a 15-cm depth per pasture. The samples were collected in cloth bags, washed, and separated to obtain only peanut rhizomes. Rhizomes were put in an oven at 105°C for 1 h and then at 60°C until dry. Total non-structural carbohydrate and N concentration were determined in rhizome samples. Analysis of TNC was performed by enzymatic digestion according to procedures described by Christiansen and Svejcar (1982). Nitrogen analysis was performed by a modification of the standard Kjeldahl procedure; therefore, the values represent total N. Samples for N analysis were digested using a modification of the aluminum block digestion procedure of Gallaher et al. (1975), and analyses of digestate for ammonia was done using semiautomated colorimetry (Hambleton, 1977).

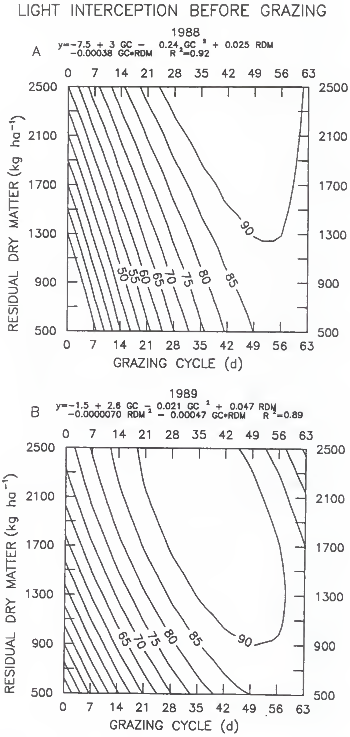
Crop growth rate is reported as the mean over each grazing season and was calculated by dividing peanut herbage accumulation by the number of days in the grazing season. The beginning of the grazing season was considered to be 14 d after last frost in spring.

Results and Discussion

Light interception before grazing (LIB)

For 1988, the model for LIB included the linear and quadratic ($P<0.01$) effects of GC, the linear ($P<0.01$) effect of RDM, and the interaction of GC by RDM ($P<0.01$) (Fig. 5.1 A; Table A-19). Light interception before grazing ranged from 28 to 90%. For 1989, there was a GC by RDM interaction ($P<0.01$) (Fig 5.1 B; Table A-20). Other terms included in the model were the linear ($P<0.01$) and quadratic ($P<0.01$) effects of GC, and the linear ($P<0.01$) and quadratic ($P=0.03$) effects of RDM. Lowest values of LIB were found with treatments of short GC and low RDM. In both seasons, interaction occurred because with short GC LIB increased as RDM increased over the entire range of RDM, while for GC longer than 35 d there was less effect of RDM.

Brougham (1956) found that differences in light interception in ryegrass (Lolium multiflorum Lam.) disappeared by 24 d after plots were defoliated to 2.5-,

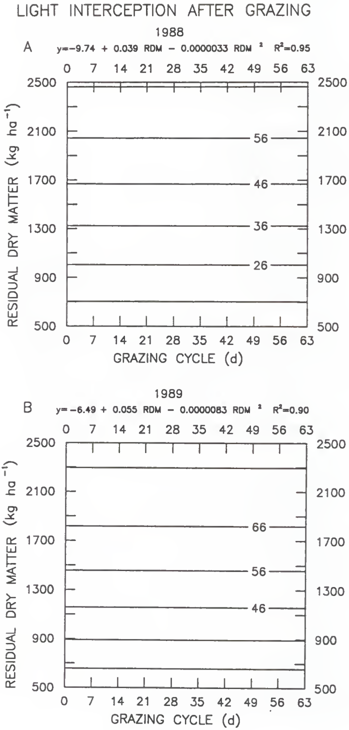


5.1. Mean light interception (%) before grazing in A) 1988 and B) 1989 grazing seasons as affected by length of grazing cycle and postgraze residual dry matter.

7.5-, and 12.5-cm cutting heights. In 1989, peanut defoliated to 500, 1500, and 2500 kg ha^{-1} RDM required approximately 49, 24, and 12 d to reach 85% light interception. Thus, differences in light interception due to RDM persisted well into regrowth periods. Light interception was practically constant throughout the grazing season for treatments with a given RDM and GC=7, since RDM was successfully maintained near to the target level.

Light interception after grazing (LIA)

For 1988, terms included in the model for LIA were the linear and quadratic ($P<0.01$ and $P=0.13$) effects of RDM (Fig. 5.2 A; Table A-21). Range for LIA was from 6 to 82%. In the second year also, LIA increased at a decreasing rate ($P<0.05$) as RDM increased (Fig. 5.2 B; Table A-22). Since this measurement was taken after grazing the only factor influencing it was the amount of herbage left in pastures after grazing (RDM). The range for LIA in 1989 was from 11 to 84%. A similar range in results was obtained by Brougham (1956), who reported light interception of 12.7, 71.6, and 96.5% after defoliation of ryegrass to heights of 2.5, 7.5, and 12.5 cm. For pastures grazed to an RDM of 2500 kg ha^{-1}, postgraze canopy architecture appeared to be affected by GC.



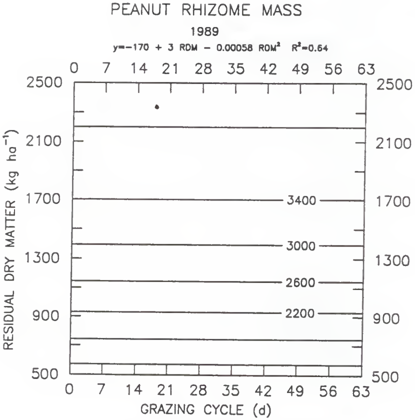
5.2. Mean light interception (%) after grazing in A) 1988 and B) 1989 as affected by length of grazing cycle and postgraze residual dry matter.

Pastures with short GC had a shorter canopy and leaves seemed to be distributed more uniformly from the base to the upper part of the stems. In treatments with long GC, most of the leaves were in the upper part of the canopy and were removed during grazing. Thus, even though LIA was maximized at high levels of RDM, in the case of long GC and high RDM treatments, most of the light was intercepted by stems instead of leaves.

Rhizome mass

Rhizome mass at the end of the 1988 grazing season and at the beginning of 1989 did not show any effect of the experimental variables. It was observed, however, that considerable decrease in rhizome mass occurred during the winter season following simulated continuous grazing when RDM was 500 kg ha^{-1}. For this treatment combination, rhizome mass decreased from 2550 to 1075 kg ha^{-1}. No noticeable changes were observed for any other treatment.

At the end of the second grazing season, the model for rhizome mass included the linear ($P=0.02$) and quadratic ($P=0.18$) effects of RDM (Fig. 5.3; Table A-23). Rhizome mass ranged from 300 to 4100 kg ha^{-1}, and lowest values were found with low levels of RDM. As RDM increased, rhizome



5.3. Peanut rhizome mass (kg ha^{-1}) in November 1989 as affected by length of grazing cycle and postgraze residual dry matter.

mass increased but the rate of change was much slower after RDM was higher than 1500 kg ha^{-1}. Svejcar and Christiansen (1987), working with Caucasian bluestem [Bothriochloa caucasica (Trin.) C.E. Hubb.], found that peak root mass was 27 and 46% lower in the first and second year of study under heavy grazing compared to a moderate grazing pressure.

Effects of decreasing stubble height on root weight of birdsfoot trefoil (Lotus corniculatus L.) have been reported by Smith and Nelson (1967). They found that decreasing stubble height from 15.2 to 7.6 or 2.5 cm caused a reduction in root weight, and similar results were found with increasing harvesting frequency. Alison and Hoveland (1989), working with the same species, reported reductions in root weight from 3.8 to 2.8 g $plant^{-1}$ when harvest interval was reduced from 42 to 21 d. They also reported that root weight decreased from 2.6 to 1.7 g $plant^{-1}$ when the stubble height was reduced from 10 to 3 cm.

In the current study, a very marked response to GC was observed at the lowest level of RDM (500 kg ha^{-1}). For the treatment combination of 500 kg ha^{-1} with continuous grazing, rhizome mass decreased from 3500 kg ha^{-1} at the beginning of the experiment in 1988 to 300 kg ha^{-1} at the end of the grazing season in 1989.

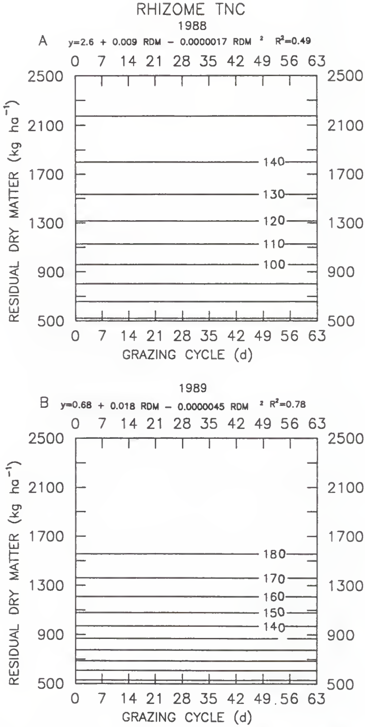
Nitrogen concentration in rhizomes

Experimental variables had no effect on N concentration in rhizomes. Although nitrogenous compounds have been recognized as important plant reserves (Perry and Moser, 1974; Smith, 1975), White (1973) suggested that they are used in respiration but are not alternately stored and utilized as are carbohydrate reserves. This may explain partially why it was not possible to detect differences due to grazing management.

Total non-structural carbohydrate concentration in rhizomes

The model for TNC was the same for 1988 and 1989, and included the linear ($P=0.04$ and $P<0.01$, respectively) and quadratic ($P=0.20$ and $P<0.01$) effects of RDM (Figs. 5.4 A and B; Tables A-24 and A-25). Lower values of TNC were found with low RDM. In these pastures, stubble height was shorter than 7 cm and there were few leaves remaining for photosynthesis after defoliation. Booysen and Nelson (1975) suggested that in tall fescue (Festuca arundinacea Schreb.) both residual leaf area and reserve carbohydrates contribute energy to regrowth. They reported that severity of defoliation influenced the dependence of regrowth on stored energy. When defoliated severely, fescue was more dependant on reserves than if defoliation was lax.

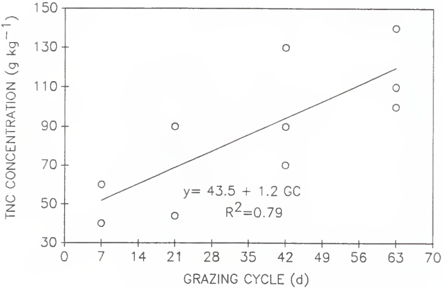
Low levels of TNC in rhizomes were associated with lowest values of rhizome mass. This differed from the data of Christiansen and Svejcar (1988) who reported that



5.4. Total non-structural carbohydrate concentration (g kg^{-1}) in peanut rhizomes in November of A) 1988 and B) 1989 as affected by length of grazing cycle and postgraze residual dry matter.

Caucasian bluestem root mass was greatest in lightly grazed swards, but root TNC concentration was higher in heavily grazed pastures. These data do not appear consistent with the theory that TNC reserves were used to support above-ground regrowth. The authors mention, however, that Caucasian bluestem adopted a prostrate growth habit under heavy grazing, and there was always residual leaf area. Therefore, there may have been little need for mobilization of root TNC to support above-ground regrowth. In the current study, rhizoma peanut developed a prostrate growth habit when defoliated closely and frequently, and there were leaves remaining close to ground level that animals were unable to graze. It was observed, however, that these leaves were small and yellow, and they probably lacked sufficient photosynthetic capacity to provide the plants energy needs, thus, TNC reserves were used for regrowth and gradually depleted. Mansfield (1989) found that yellow leaves were low in N concentration and this characteristic was related to single leaf carbon exchange rate. As N concentration increased from 1.2 to 2.2%, single leaf carbon exchange rate increased and the correlation between these two variables was 0.64.

The most pronounced effect of GC on TNC concentration in rhizomes was found for the RDM of 500 kg ha^{-1}. For this RDM level, TNC increased linearly ($P<0.07$) as GC increased (Fig. 5.5). Based on 1989 data, pastures with RDM of 1500

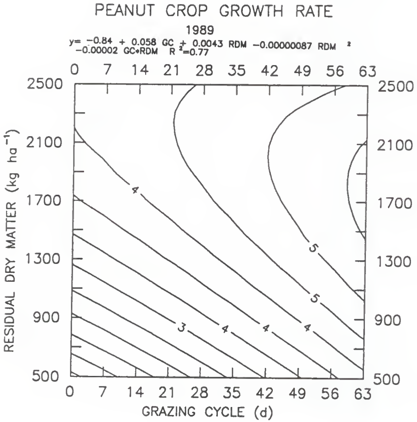


5.5. Length of grazing cycle effect on rhizome total non-structural carbohydrate (TNC) concentration (g kg^{-1}) in November 1988 and 1989 for rhizoma peanut grazed to a postgraze residual dry matter of 500 kg ha^{-1}.

kg ha^{-1} or greater had sufficient residual leaf area remaining after grazing to avoid depleting TNC pools regardless of GC.

Peanut crop growth rate (CGR)

For 1988, there was no effect of the experimental variables on peanut CGR. Range for CGR was from 3.6 to 5.1 g m^{-2} d^{-1}. Crop growth rate was calculated from peanut HA, and this response variable did not show as marked an effect of the experimental variables during the first year of study as in the second year. This was due to the fact that most herbage accumulation occurred early in the 1988 grazing season when the effect of treatments was not yet manifested fully. For 1989, there was an interaction of GC by RDM ($P=0.05$). This occurred because the effect of GC was more important at low levels of RDM, and as RDM increased the effect of GC became less pronounced. The model for CGR also included the linear effects of GC ($P<0.01$) and RDM ($P<0.01$), and the quadratic effect of RDM ($P=0.02$) (Fig. 5.6; Table A-26). Highest values of CGR were found with intermediate levels of RDM and GC longer than 35 d. Similar results have been reported by Beltranena et al. (1981), who found that as cutting interval of rhizoma peanut increased between 2 and 12 wk, LAI increased from 1.5 to 7.6, and CGR from 4.7 to 7.1 g m^{-2} d^{-1}. No differences were found, however, with clipping intervals longer than 6 wk.



5.6. Mean peanut crop growth rate (g m^2 d^{-1}) in 1989 as affected by length of grazing cycle and postgraze residual dry matter.

Conclusions

Residual dry matter was the most important experimental variable influencing most responses measured. For both years, light interception after grazing, rhizome mass, and rhizome TNC increased at a decreasing rate as RDM increased. No major changes in rhizome TNC and rhizome mass occurred, however, when RDM was higher than 1700 kg ha^{-1}. Maximum levels of CGR were found within the range where TNC was greatest. Large changes in TNC were found only for pastures grazed to the lowest RDM, suggesting that the amount of leaf remaining after grazing was not enough to support regrowth, thus TNC pools were gradually depleted. In these low RDM pastures, GC was important, and the depletion in carbohydrate pools was greater in treatments with short GC. Likewise, for most of the response variables the effect of GC was much greater at low levels of RDM, and its importance decreased as RDM increased.

These data suggest that poor persistence of rhizoma peanut when grazed to low RDM and short GC (Chapter IV) is due to the combined effects of inadequate reserves and little leaf remaining after grazing to support regrowth. Reserve status changed little when RDM was higher than 1700 kg ha^{-1}, regardless of GC, indicating that residual leaf was the main source of energy for regrowth in these treatments.

When RDM was 500 kg ha^{-1}, however, TNC concentration decreased linearly with decreasing GC. This suggests that TNC reserves were depleted to supply energy for regrowth. The degree to which reserves were restored was directly related to the length of time before another grazing event. It can be concluded that length of time between grazings of peanut is not very important to persistence if pastures are defoliated to an RDM of 1700 kg ha^{-1} or higher. If grazed closely, the length of this interval is critical. In general, grazing rhizoma peanut to an RDM below 1000 kg ha^{-1} is not recommended when persistence is a high priority.

CHAPTER VI
EFFECT OF GRAZING MANAGEMENT ON NUTRITIVE VALUE OF RHIZOMA PEANUT

Introduction

Mott and Moore (1985) defined nutritive value as the chemical composition, digestibility, and nature of the digested products of a forage. In their forage evaluation scheme, Mott and Moore (1970) advised use of laboratory methods when screening plants for agronomic characteristics or when looking at effects of grazing on pastures. Crude protein (CP) and in vitro digestible organic matter concentration (IVDOM) were suggested as useful assays for comparing nutritive value of a large number of samples.

Rhizoma peanut (Arachis glabrata Benth.) has demonstrated high nutritive value under clipping. Crude protein and mineral concentrations were similar to those of alfalfa (Medicago sativa L.), and peanut was low in crude fiber (Blickensderfer et al., 1964). Beltranena et al. (1980) reported decreases in CP and IVDOM from 220 to 150 g kg^{-1} of dry matter (DM) and 740 to 640 g kg^{-1} OM, respectively, as cutting interval increased from 2 to 12 wk. Under grazing, Sollenberger et al. (1989) reported values of IVDOM consistently higher than 700 g kg^{-1} OM, and CP higher than 160 g kg^{-1} DM. No information is available, however, about the effects of a wide range of grazing managements on nutritive value of rhizoma peanut. These data are needed so that grazing management decisions can compromise appropriately between plant and animal requirements for optimum productivity.

The objectives of this study were a) to determine the effect of postgraze residual dry matter (RDM) and length of grazing cycle (GC) on CP and IVDOM of total and component herbage consumed and b) to define the range of grazing management where nutritive value of rhizoma peanut pastures is optimum.

Materials and Methods

This study was conducted in 1988 and 1989 at the Forage Evaluation Field Laboratory of the Beef Research Unit, near Gainesville, Florida. Rhizoma peanut pasture layout, grazing procedure, and statistical analysis used in this study were described in Chapter III. Experimental variables were three levels of RDM (500, 1500, and 2500 kg ha^{-1}) and four levels of GC (7, 21, 42, and 63 d). A complete factorial arrangement of the 12 treatments was evaluated in two replications of a randomized complete block design. Data were analyzed with response surface methodology using a second order polynomial model.

Sampling procedure

Nutritive value of both herbage accumulated and herbage consumed (disappeared during grazing) was calculated. Because the data for each showed the same effects of the experimental variables, only data on herbage consumed basis are presented.

Samples used to determine nutritive value of herbage consumed were the before and after grazing forage samples described in chapter III. A difference technique (Frame, 1981) was used to estimate nutritive value of total, peanut, and grass herbage consumed. No data are presented on broadleaf weeds because they were generally avoided by grazing steers. Data reported are for the 1988 and 1989 grazing seasons and were calculated by summing CP or DOM disappearance over cycles and dividing by DM or OM disappearance, respectively, also summed over cycles.

Laboratory analysis

Samples of peanut and grass were ground to 1 mm and analyzed at the Forage Evaluation Support Laboratory of the University of Florida for N concentration and IVDOM. The digestibility procedure used was a modification of the two-stage technique (Moore and Mott, 1974), and included a) incubation of a sample with rumen microorganisms for 48 h followed by b) 44-h incubation with acid-pepsin. Results express g of OM that were digested or disappeared per kg of OM. The N analysis was performed using a modification of the standard Kjeldahl procedure; therefore, the values represent total plant N. Samples were digested using a modification of the aluminum block digestion procedure of Gallaher et al. (1975), and analyses of digestate for ammonia were done using the Technicon Autoanalyzer II (Hambleton, 1977). Percentage CP was determined by multiplying the N percentage by 6.25, and the results express g of CP per kg of DM.

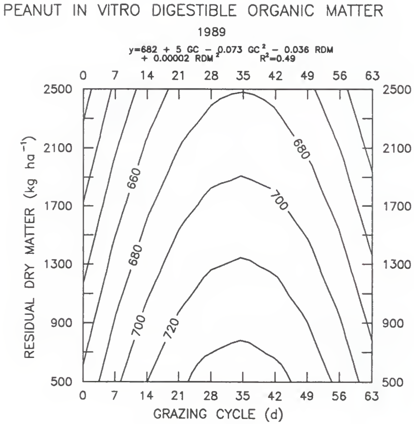
Results and Discussion

Effect of Grazing Management on Peanut Nutritive Value

In vitro digestible organic matter

In 1988, there was no response of peanut IVDOM to the experimental variables. For 1989, IVDOM was primarily affected by GC (linear and quadratic effects, $P<0.01$), but the quadratic effect of RDM ($P=0.19$) was included in the model also (Fig. 6.1; Table A-27). Range for this response variable was from 600 to 740 g kg^{-1}, with highest values occurring for intermediate levels of GC and RDM below 1300 kg ha^{-1}.

It was noticed that amount of leaves as well as their size in low RDM and short GC treatments was reduced and probably the leaf/stem ratio was smaller than in treatments with intermediate values of RDM. This may explain partially the lower values of IVDOM obtained with these managements,



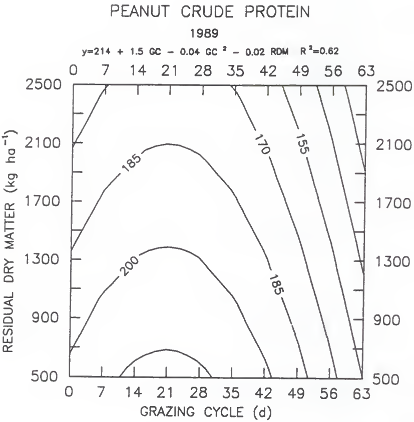
6.1. In vitro digestible organic matter (g kg^{-1}) in peanut herbage consumed as affected by length of grazing cycle and postgraze residual dry matter.

compared with treatments with intermediate values of GC and RDM. Beltranena et al. (1980) in a clipping study found decreases in peanut IVDOM from 740 to 640 g kg^{-1} as cutting interval was increased from 2 to 12 wk. Mansfield (1990) reported that values of IVDOM were 150 g kg^{-1} lower in stems as compared to leaves. Increasing maturity and decreasing leaf/stem ratio likely resulted in lower IVDOM of peanut consumed for long GC. Although it was possible to identify some effect of grazing management on peanut IVDOM, the lowest value of the range can be considered high for a tropical forage. These data correspond well to those of Sollenberger et al. (1989), who managed rhizoma peanut for an RDM of 1800 kg ha^{-1} and a 42-d GC. Reported IVDOM values for hand-plucked herbage in that study were consistently higher than 700 g kg^{-1} throughout the grazing season.

Crude protein concentration

For 1988, peanut CP was not affected by grazing management. In 1989, the model for this response variable included the linear effects of GC and RDM ($P=0.19$ and $P<0.01$, respectively), and the quadratic ($P=0.03$) effect of GC (Fig. 6.2; Table A-28). Peanut CP ranged from 100 to 230 g kg^{-1}, with lowest values in treatment combinations of long GC and high RDM.

Similar results have been reported by Beltranena et al. (1980) who observed decreases in rhizoma peanut CP from 220



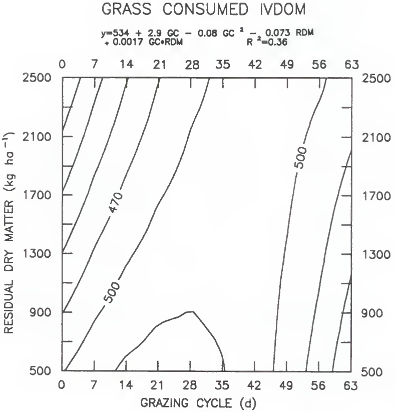
6.2. Crude protein concentration (g kg^{-1}) in peanut consumed as affected by length of grazing cycle and postgraze residual dry matter.

to 150 g kg^{-1} as cutting interval increased from 2 to 12 wk. Prine et al. (1981a) reported a range in CP concentration of 120 to 190 g kg^{-1} in rhizoma peanut under clipping. Range of CP concentration obtained in this study is close to results reported for tropical legumes by other researchers (Canudas-Lara, 1988; Maraschin et al., 1981) in different parts of the world. Similar to peanut IVDOM, highest CP values were found with low RDM and short to intermediate GC. As observed with IVDOM, CP decreased as GC increased above 42 d. It is likely that the leaf/stem ratio was lower in long GC, and that may have contributed to the effect observed. Differences in N concentration in leaves and stems of rhizoma peanut have been reported by Mansfield (1990), who found that stems were 440 g kg^{-1} lower as compared to leaves.

Effect of Grazing Management on Grass Nutritive Value

Grass in vitro organic matter digestibility

There was no effect of grazing management on grass IVDOM for the grazing season in 1988, but in 1989 there was a GC by RDM interaction (P=0.05). The interaction occurred because the effect of RDM was more pronounced at short GC, i.e., IVDOM decreasing with increasing RDM, than at long GC. Other terms included in the model were the linear and quadratic effects of GC (P=0.38 and P=0.06, respectively), and the linear effect of RDM (P=0.03) (Fig. 6.3; Table A-



6.3. In vitro digestible organic matter (g kg^{-1}) in grass herbage consumed in 1989 as affected by length of grazing cycle and postgraze residual dry matter.

29). Highest values of this response variable were found with levels of RDM of 900 kg ha^{-1} or lower, and GC between 10 and 35 d. Range for grass IVDOM was from 390 to 560 g kg^{-1}, which is in the general range of 350 to 720 g kg^{-1} reported for tropical grasses by Mott (1981).

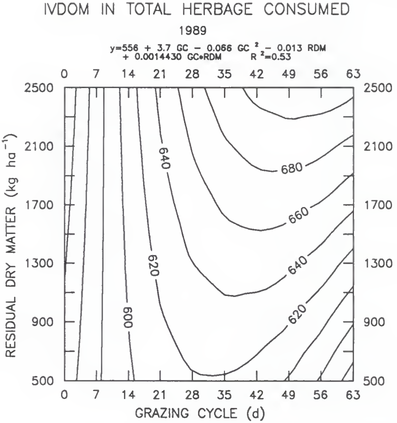
Crude protein concentration

Grass CP concentration was not affected by the grazing management treatments applied in either grazing season. This may seem unusual, especially when such a wide range of grazing management was evaluated. A possible explanation for this, is that grass in pastures where peanut did not persist benefitted from N released by decomposing legume residues, while grass in strong peanut swards may have received N due to leaf drop and sloughing of nodules following defoliation.

Nutritive Value of Total Herbage Consumption

In vitro digestible organic matter

There was no effect of the experimental variables on IVDOM of total herbage consumed in 1988. For 1989, there was a GC by RDM interaction (P=0.03) (Fig. 6.4; Table A-30). This occurred because with GC of approximately 21 d or less, there was little effect of RDM on the response, but at higher GC most variation in the response was due to RDM. As RDM increased, the proportion of peanut in the total herbage consumed increased, and IVDOM in peanut was higher than in



6.4. In vitro digestible organic matter (g kg^{-1}) in total herbage consumed in 1989 as affected by length of grazing cycle and postgraze residual dry matter.

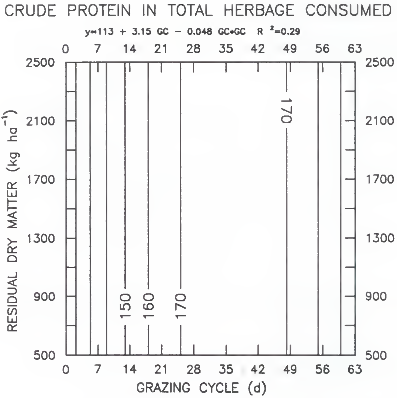
grass. Therefore, maximum values of IVDOM in total herbage consumption were found with GC longer than 21 d, and RDM higher than 1500 kg ha^{-1}. The linear (P=0.16) and quadratic (P=0.05) effects of GC, and the linear effect of RDM (P=0.58), were included in the model also.

Crude protein concentration

There was no effect of grazing management on this response for 1988. In 1989, the model for total herbage CP included the linear (P=0.02) and quadratic (P=0.01) effects of GC (Fig 6.5; Table A-31). Range for this response variable was from 100 to 190 g kg^{-1}. Grazing managements which favored grass accumulation had lower values of total herbage consumed CP, since CP concentration was lower in grass than in peanut. Higher CP concentration in legumes as compared to tropical grasses is a typical response and has been illustrated by Mott (1981) and Minson (1980).

Conclusions

In most cases, GC explained the highest proportion of the variation in the response variables discussed in this chapter. Maximum nutritive value of peanut was found generally with intermediate to low levels of RDM and GC. Even when it was possible to detect variation in nutritive value of peanut consumed, peanut IVDOM and CP were considered quite high and desirable under a broad range of grazing management. Maximum values of IVDOM and CP in total



6.5. Crude protein concentration (g kg^{-1}) in total herbage consumed in 1989 as affected by length of grazing cycle and postgraze residual dry matter.

herbage consumed were found with grazing managements in which rhizoma peanut was the dominant component.

Based on the results of this study, the most important factor affecting nutritive value of herbage consumed on peanut pastures is the proportion of peanut in the sward canopy. To maximize nutritive value, therefore, management practices selected must favor peanut persistence (see Chapter IV).

CHAPTER VII
GENERAL DISCUSSION

The objective of this chapter is to discuss both experimental and practical implications of the studies conducted. The primary objective of this research was to quantify and explain the responses of rhizoma peanut (Arachis glabrata Benth.) to grazing stress. The work was undertaken because this information is needed by producers to obtain greatest benefit from use of peanut pastures. Specifically, producers need to be able to make grazing management decisions with an understanding of their potential effect on stand life, peanut productivity, and peanut nutritive value. Then appropriate compromises between plant and animal requirements can be made.

These studies were conducted in 1988 and 1989 at the Forage Evaluation Field Laboratory of the University of Florida's Beef Research Unit. Treatments included all combinations of three levels of postgraze residual dry matter (RDM; 500, 1500, and 2500 kg ha^{-1}) with four lengths of grazing cycle (GC; 7, 21, 42, and 63 d). The 12 treatments were randomly assigned to 400-m^2 pastures within each of two blocks in a randomized complete block design.

The data were analyzed by response surface methodology using least squares regression.

Practical Implications for Rhizoma Peanut Grazing Management

In these studies, rhizoma peanut performed well over a wide range of grazing management, suggesting that flexibility exists for its use in production environments. To achieve maximum productivity, rotational grazing with regrowth intervals of 35 d or longer and RDM of more than 1100 kg ha^{-1} will be needed. If willing to sacrifice some productivity in exchange for less intensive management, then continuous stocking of peanut is a viable option if herbage mass is maintained at approximately 2000 kg ha^{-1} or higher.

Despite its potential for flexible management, care must be taken to avoid severely overgrazing peanut pastures. Even when the highest grazing stress treatments did not eliminate rhizoma peanut, large changes in botanical composition, rhizome mass, and plant reserves occurred by the end of 1 yr of overgrazing. These changes affected negatively pasture persistence and productivity during the second year of study with a reduction of peanut herbage accumulation of more than 80%. The question may be asked if an overgrazed stand can be restored. At the beginning of the second grazing season, percentage peanut in severely overgrazed (GC=7 d, RDM=500 kg ha^{-1}) pastures was 33%, and there was 1100 kg ha^{-1} of rhizome mass. This suggests that restoration of these pastures may be possible by modification of the grazing management and/or application of herbicide for grass control in a second year. Thus, if conditions demand it, rhizoma peanut may be severely overgrazed without losing the stand in the first year, and the possibility exists of stand recovery.

Even when marked changes in botanical composition occurred during the two years of this trial, total herbage accumulation did not show the effect of the experimental variables. This was due to a substitution effect; as rhizoma peanut decreased, common bermudagrass [Cynodon dactylon (L.) Pers.] increased. Bermudagrass was very productive in overgrazed pastures in this study, possibly due to recycling of legume residues from dead plants. Approximately 3400 kg ha^{-1} of rhizome mass alone disappeared during the study in treatments of simulated continuous grazing to 500 kg ha^{-1}. Some of this loss was used for peanut topgrowth, but some was used to maintain growth rate of bermudagrass present on pastures. Therefore, the high productivity of bermudagrass achieved under treatments of low RDM and short GC, was due, at least partially, to the N released from peanut decomposition. This suggests that differences in total herbage accumulation may become important in subsequent years, when N from peanut is no longer available to the grass.

Decreases in productivity were related to reduced light interception after grazing, peanut rhizome mass, and rhizome total non-structural carbohydrate concentration. No major changes in rhizome TNC and rhizome mass occurred when RDM was 1700 kg ha^{-1} or higher. Maximum levels of peanut growth rate were found within the range where TNC was greatest. Large changes in TNC were found only for pastures grazed to the lowest RDM, suggesting that the amount of leaf remaining after grazing was not enough to support regrowth, thus TNC pools were gradually depleted. In these low RDM pastures, GC played an important role influencing reserve status, and the depletion in carbohydrate pools was greater in treatments with short GC. For most of the response variables the GC effect was much greater at low levels of RDM, and its importance decreased as RDM increased.

Nutritive value of peanut consumed was higher at short to intermediate levels of GC and low to intermediate levels of RDM. Regardless of management, peanut in vitro digestible organic matter and crude protein were quite high. On a total canopy basis, treatments which maximized peanut persistence had near maximum nutritive value. Thus, grazing management decisions with peanut may be made primarily on basis of pasture persistence and productivity.

Implications for Future Defoliation Stress Studies

Unlike many tropical legumes, it was observed in these studies that rhizoma peanut persists and performs well over a relatively wide range of grazing management. Responses of rhizoma peanut to grazing management became more pronounced in the second year of study than in the first one, primarily because most herbage accumulation in the first year occurred prior to when the effect of treatments was manifested fully. In fact, the range in pasture productivity during the first year was relatively small and rhizoma peanut appeared to be very productive under any grazing management. This is an important consideration when evaluating plant responses to grazing stress, especially when dealing with plants having a well-developed structure to accumulate reserves like rhizoma peanut. Pasture productivity may be sustained at high levels during the first season at the expense of plant reserves, but once the pool of reserves is depleted, pastures managed in this way may fail to achieve maximum productivity and persistence.

In this context, it may be important to consider the possibility of conducting these type of experiments for periods longer than two grazing seasons. A potential approach may be to apply the grazing treatments during the first year without taking detailed measurements of pasture productivity. Changes in botanical composition and plant reserves can be monitored at different points in time during the grazing season. This would provide the opportunity to observe responses to grazing management for a longer period of time without increasing considerably the amount of time and economic resources needed.

The author believes that rhizoma peanut is a promising forage that possesses exceptional persistence under grazing, a trait that has been recognized as one of the most important factors limiting the extensive use of legumes in tropical regions. Additionally, Sollenberger et al. (1989) have reported excellent animal performance under grazing on peanut. There is, however, one problem that must be solved before rhizoma peanut can be successfully accepted and used extensively on a large scale by producers. That problem is establishment. In this context, research efforts with rhizoma peanut should be focused to find alternatives to make the establishment process cheaper, faster, and more reliable.

Table A-1. Least squares regression analysis of peanut herbage accumulation (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	31693885.6791	10.05	0.0009
Error	21	33113262.1543		
Corrected Total	23	64807147.8333		

R-Square	C.V.	PHA† Mean
0.489049	15.03056	8354.4166667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	6393377.1531	4.05	0.0570
RDM§	1	25300508.5260	16.05	0.0006

Source	DF	Type III SS	F Value	Pr > F
GC	1	9958990.8121	6.32	0.0202
RDM	1	25300508.5260	16.05	0.0006

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	5312.469181	7.24	0.0001	733.38006920
GC	30.615662	2.51	0.0202	12.18224495
RDM	1.237969	4.01	0.0006	0.30905559

†PHA=peanut accumulation (kg ha^{-1}).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-2. Least squares regression analysis of peanut herbage accumulation (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	118212529.883	16.35	0.0001
Error	19	34345740.617		
Corrected Total	23	152558270.500		

R-Square	C.V.	PHA† Mean
0.774868	18.44239	7290.2500000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	26310603.4297	14.55	0.0012
RDM§	1	75977511.0614	42.03	0.0001
RDM*RDM	1	8174614.4387	4.52	0.0468
GC*RDM	1	7749800.9527	4.29	0.0523

Source	DF	Type III SS	F Value	Pr > F
GC	1	25915305.0924	14.34	0.0012
RDM	1	28888802.4387	15.98	0.0008
RDM*RDM	1	12414540.0604	6.87	0.0168
GC*RDM	1	7749800.9527	4.29	0.0523

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-1523.697755	-1.04	0.3110	1463.9611993
GC	104.703421	3.79	0.0012	27.65300608
RDM	7.783405	4.00	0.0008	1.94699348
RDM*RDM	-0.001591	-2.62	0.0168	0.00060697
GC*RDM	-0.034413	-2.07	0.0523	0.01662029

†PHA=peanut accumulation (kg ha^{-1}).

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

Table A-3. Least squares regression analysis of grass herbage accumulation (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	10718368.9239	4.39	0.0110
Error	19	11585098.7011		
Corrected Total	23	22303467.6250		

R-Square	C.V.	GHA† Mean
0.480570	42.67868	1829.6250000

Source	DF	Type I SS	F Value	Pr > F
GC†	1	1682520.41525	2.76	0.1131
GC*GC	1	1249090.74628	2.05	0.1686
RDM§	1	6326448.48491	10.38	0.0045
RDM*RDM	1	1460309.27749	2.39	0.1382

Source	DF	Type III SS	F Value	Pr > F
GC	1	2697493.66930	4.42	0.0490
GC*GC	1	1748958.15742	2.87	0.1067¶
RDM	1	2929800.18868	4.80	0.0410
RDM*RDM	1	1460309.27749	2.39	0.1382#

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	4836.778584	5.91	0.0001	818.95957557
GC	-72.663354	-2.10	0.0490	34.54683710
GC*GC	0.808855	1.69	0.1067	0.47758884
RDM	-2.002709	-2.19	0.0410	0.91363350
RDM*RDM	0.000422	1.55	0.1382	0.00027300

†GHA=grass accumulation (kg ha^{-1}).

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

¶In the complete model P=0.08.

#In the complete model P=0.08.

Table A-4. Least squares regression analysis of grass herbage accumulation (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	97475735.3960	20.41	0.0001
Error	19	22690493.9374		
Corrected Total	23	120166229.3333		

R-Square	C.V.	GHA† Mean
0.811174	28.69903	3807.8333333

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	8211667.5918	6.88	0.0168
RDM§	1	74045632.7448	62.00	0.0001
RDM*RDM	1	12202358.9589	10.22	0.0048
GC*RDM	1	3016076.1004	2.53	0.1285

Source	DF	Type III SS	F Value	Pr > F
GC	1	9479431.5050	7.94	0.0110
RDM	1	28533681.7460	23.89	0.0001
RDM*RDM	1	14741241.5075	12.34	0.0023
GC*RDM	1	3016076.1004	2.53	0.1285¶

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	11389.81395	9.57	0.0001	1189.9126963
GC	-63.32480	-2.82	0.0110	22.47645842
RDM	-7.73542	-4.89	0.0001	1.58252299
RDM*RDM	0.00173	3.51	0.0023	0.00049335
GC*RDM	0.02147	1.59	0.1285	0.01350903

†GHA=grass accumulation (kg ha^{-1}).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).
¶In the complete model P=0.10.

Table A-5. Least squares regression analysis of total herbage grazing efficiency (1988).

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Source                  DF    Sum of Squares      F Value        Pr > F

Model                    1     1257.76465045        98.81        0.0001

Error                   22      280.02806493

Corrected Total         23     1537.79271537

                  R-Square              C.V.              OGE† Mean

                  0.817903          4.257716            83.79397084


Source                  DF       Type I SS        F Value        Pr > F

RDM‡                     1     1257.76465045        98.81        0.0001

Source                  DF     Type III SS        F Value        Pr > F

RDM                      1     1257.76465045        98.81        0.0001


                                  T for H0:     Pr > |T|    Std Error of
Parameter          Estimate     Parameter=0                   Estimate

INTERCEPT       97.94546352           61.25       0.0001      1.59907181
RDM             -0.00865579           -9.94       0.0001      0.00087076
```

†OGE=grazing efficiency (%).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-6. Least squares regression analysis of total herbage grazing efficiency (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	982.10094800	124.19	0.0001
Error	21	166.06616101		
Corrected Total	22	1148.16710901		

R-Square	C.V.	OGE† Mean
0.855364	3.187084	88.23429168

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	982.10094800	124.19	0.0001

Source	DF	Type III SS	F Value	Pr > F
RDM	1	982.10094800	124.19	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	100.0382935	82.63	0.0001	1.21068096
RDM	-0.0083662	-11.14	0.0001	0.00075073

†OGE=grazing efficiency (%).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-7. Least squares regression analysis of peanut grazing efficiency (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	1475.95146112	79.61	0.0001
Error	22	407.88187221		
Corrected Total	23	1883.83333333		

R-Square	C.V.	PGE† Mean
0.783483	5.060709	85.08333333

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	1475.95146112	79.61	0.0001

Source	DF	Type III SS	F Value	Pr > F
RDM	1	1475.95146112	79.61	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	100.4132077	52.03	0.0001	1.92989815
RDM	-0.0093765	-8.92	0.0001	0.00105090

†PGE=grazing efficiency (%).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-8. Least squares regression analysis of peanut grazing efficiency (1989).

Source	DF	Sum of Squaress	F Value	Pr > F
Model	3	1397.65478250	75.85	0.0001
Error	20	122.84521750		
Corrected Total	23	1520.50000000		

R-Square	C.V.	PGE† Mean
0.919207	2.792517	88.75000000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	59.45691610	9.68	0.0055
RDM§	1	1316.81754298	214.39	0.0001
GC*RDM	1	21.38032341	3.48	0.0768

Source	DF	Type III SS	F Value	Pr > F
GC	1	3.41584176	0.56	0.4645¶
RDM	1	575.06058447	93.62	0.0001
GC*RDM	1	21.38032341	3.48	0.0768

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	103.5405654	51.84	0.0001	1.99724726
GC	-0.0371730	-0.75	0.4645	0.04984750
RDM	-0.0110481	-9.68	0.0001	0.00114181
GC*RDM	0.0000549	1.87	0.0768	0.00002942

†PGE=peanut grazing efficiency (%).

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

¶In the complete model P=0.78.

Table A-9. Least squares regression analysis of grass grazing efficiency (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	1730.28668049	25.35	0.0001
Error	20	455.04665285		
Corrected Total	23	2185.33333333		

R-Square	C.V.	GGE† Mean
0.791772	6.141554	77.66666667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	42.67120181	1.88	0.1860
GC*GC	1	498.44931437	21.91	0.0001
RDM§	1	1189.16616430	52.27	0.0001

Source	DF	Type III SS	F Value	Pr > F
GC	1	557.38140285	24.50	0.0001
GC*GC	1	610.25969459	26.82	0.0001
RDM	1	1189.16616430	52.27	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	102.7970817	27.75	0.0001	3.70468196
GC	-1.0441581	-4.95	0.0001	0.21096140
GC*GC	0.0151043	5.18	0.0001	0.00291645
RDM	-0.0085084	-7.23	0.0001	0.00117691

†GGE=grass grazing efficiency (%).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-10. Least squares regression analysis of grass grazing efficiency (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	1369.92303866	54.41	0.0001
Error	21	528.68565700		
Corrected Total	22	1898.60869565		

R-Square	C.V.	GGE† Mean
0.721540	5.893920	85.13043478

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	1369.92303866	54.41	0.0001

Source	DF	Type III SS	F Value	Pr > F
RDM	1	1369.92303866	54.41	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	99.07160686	45.86	0.0001	2.16016987
RDM	-0.00988096	-7.38	0.0001	0.00133949

†GGE=grass grazing efficiency (%).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-11. Least squares regression analysis of peanut percentage in herbage accumulation (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	1263.77134962	6.84	0.0014
Error	19	878.18698371		
Corrected Total	23	2141.95833333		

R-Square	C.V.	PPCHA† Mean
0.590007	8.371747	81.20833333

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	164.14994331	3.55	0.0749
GC*GC	1	111.22615030	2.41	0.1373
RDM§	1	867.81279551	18.78	0.0004
RDM*RDM	1	120.58246050	2.61	0.1228

Source	DF	Type III SS	F Value	Pr > F
GC	1	261.37573743	5.65	0.0281
GC*GC	1	165.70144374	3.59	0.0736
RDM	1	287.17489650	6.21	0.0221
RDM*RDM	1	120.58246050	2.61	0.1228¶

INTERCEPT	50.20466597	7.04	0.0001	7.13027195
GC	0.71526646	2.38	0.0281	0.30078205
GC*GC	-0.00787307	-1.89	0.0736	0.00415813
RDM	0.01982769	2.49	0.0221	0.00795455
RDM*RDM	-0.00000384	-1.62	0.1228	0.00000238

†PPCHA=peanut percentage in herbage accumulation.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).
¶In the complete model P=0.06.

Table A-12. Least squares regression analysis of peanut percentage in herbage accumulation (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	9216.71362843	21.94	0.0001
Error	19	1995.28637157		
Corrected Total	23	11212.00000000		

R-Square	C.V.	PPCHA† Mean
0.822040	15.64532	65.50000000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	773.55555556	7.37	0.0138
RDM§	1	7237.27514837	68.92	0.0001
RDM*RDM	1	446.12881519	4.25	0.0532
GC*RDM	1	759.75410931	7.23	0.0145

Source	DF	Type III SS	F Value	Pr > F
GC	1	1591.22566583	15.15	0.0010
RDM	1	2208.05285146	21.03	0.0002
RDM*RDM	1	783.20438100	7.46	0.0133
GC*RDM	1	759.75410931	7.23	0.0145

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-10.05346269	-0.90	0.3789	11.15824111
GC	0.82044334	3.89	0.0010	0.21076987
RDM	0.06804709	4.59	0.0002	0.01483989
RDM*RDM	-0.00001263	-2.73	0.0133	0.00000463
GC*RDM	-0.00034073	-2.69	0.0145	0.00012668

†PPCHA=peanut percentage in herbage accumulation.

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

Table A-13. Least squares regression analysis of grass percentage in herbage accumulation (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	1271.19052051	6.30	0.0021
Error	19	958.14281282		
Corrected Total	23	2229.33333333		

R-Square	C.V.	GPCHA† Mean
0.570211	39.08977	18.16666667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	172.44897959	3.42	0.0800
GC*GC	1	99.00049547	1.96	0.1773
RDM§	1	852.01389818	16.90	0.0006
RDM*RDM	1	147.72714726	2.93	0.1033

Source	DF	Type III SS	F Value	Pr > F
GC	1	245.29064027	4.86	0.0399
GC*GC	1	151.00476044	2.99	0.0998
RDM	1	325.30973263	6.45	0.0200
RDM*RDM	1	147.72714726	2.93	0.1033¶

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	49.68462967	6.67	0.0001	7.44779509
GC	-0.69290822	-2.21	0.0399	0.31417639
GC*GC	0.00751582	1.73	0.0998	0.00434330
RDM	-0.02110316	-2.54	0.0200	0.00830878
RDM*RDM	0.00000425	1.71	0.1033	0.00000248

†GPCHA=grass percentage in herbage accumulation.

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

¶In the complete model P=0.05.

Table A-14. Least squares regression analysis of grass percentage in herbage accumulation (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	9215.01638949	22.36	0.0001
Error	19	1957.94194384		
Corrected Total	23	11172.95833333		

R-Square	C.V.	GPCHA† Mean
0.824761	30.72283	33.04166667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	678.34722222	6.58	0.0189
RDM§	1	7286.64519346	70.71	0.0001
RDM*RDM	1	491.80257065	4.77	0.0417
GC*RDM	1	758.22140316	7.36	0.0138

Source	DF	Type III SS	F Value	Pr > F
GC	1	1521.70506018	14.77	0.0011
RDM	1	2295.24566212	22.27	0.0001
RDM*RDM	1	840.46682767	8.16	0.0101
GC*RDM	1	758.22140316	7.36	0.0138

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	108.6927688	9.83	0.0001	11.05332726
GC	-0.8023206	-3.84	0.0011	0.20878813
RDM	-0.0693776	-4.72	0.0001	0.01470036
RDM*RDM	0.0000131	2.86	0.0101	0.00000458
GC*RDM	0.0003404	2.71	0.0138	0.00012549

†GPCHA=grass percentage in herbage accumulation.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-15. Least squares regression analysis of peanut percentage in pregraze herbage mass for the last grazing cycle (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	7123.58370597	13.22	0.0001
Error	19	2560.04129403		
Corrected Total	23	9683.62500000		

R-Square	C.V.	PPCP† Mean
0.735632	15.81971	73.37500000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	447.85969388	3.32	0.0841
RDM§	1	5448.32132040	40.44	0.0001
RDM*RDM	1	405.25343448	3.01	0.0991
GC*RDM	1	822.14925721	6.10	0.0231

Source	DF	Type III SS	F Value	Pr > F
GC	1	1516.02936751	11.25	0.0033
RDM	1	2056.12623340	15.26	0.0009
RDM*RDM	1	837.97560520	6.22	0.0220
GC*RDM	1	822.14925721	6.10	0.0231

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-8.248913784	-0.53	0.6009	15.50420018
GC	0.892023424	3.35	0.0033	0.26593110
RDM	0.065497644	3.91	0.0009	0.01676670
RDM*RDM	-0.000010812	-2.49	0.0220	0.00000434
GC*RDM	-0.000358298	-2.47	0.0231	0.00014505

†PPCP=peanut percentage in pregraze herbage mass.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-16. Least squares regression analysis of peanut percentage in pregraze herbage mass for the last grazing cycle (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	16547.8528773	35.36	0.0001
Error	19	2222.6471227		
Corrected Total	23	18770.5000000		

R-Square	C.V.	PPCP† Mean
0.881588	16.83392	64.25000000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	794.2959184	6.79	0.0174
RDM§	1	11412.4306385	97.56	0.0001
RDM*RDM	1	820.4936998	7.01	0.0159
GC*RDM	1	3520.6326206	30.10	0.0001

Source	DF	Type III SS	F Value	Pr > F
GC	1	4714.48934337	40.30	0.0001
RDM	1	5419.33527107	46.33	0.0001
RDM*RDM	1	1944.01820030	16.62	0.0006
GC*RDM	1	3520.63262063	30.10	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-48.61186397	-4.13	0.0006	11.77682936
GC	1.41221245	6.35	0.0001	0.22245448
RDM	0.10660507	6.81	0.0001	0.01566258
RDM*RDM	-0.00001990	-4.08	0.0006	0.00000488
GC*RDM	-0.00073348	-5.49	0.0001	0.00013370

†PPCP=peanut percentage in pregraze herbage mass.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-17. Least squares regression analysis of grass percentage in pregraze herbage mass for the last grazing cycle (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	7224.21118278	13.78	0.0001
Error	19	2489.41381722		
Corrected Total	23	9713.62500000		

R-Square	C.V.	GPCP† Mean
0.743719	43.39896	26.37500000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	496.12500000	3.79	0.0666
RDM§	1	5444.51982431	41.55	0.0001
RDM*RDM	1	427.78398608	3.26	0.0866
GC*RDM	1	855.78237239	6.53	0.0193

Source	DF	Type III SS	F Value	Pr > F
GC	1	1594.29674187	12.17	0.0025
RDM	1	2126.86197693	16.23	0.0007
RDM*RDM	1	880.25573344	6.72	0.0179
GC*RDM	1	855.78237239	6.53	0.0193

INTERCEPT	109.2949639	7.15	0.0001	15.28883627
GC	-0.9147597	-3.49	0.0025	0.26223714
RDM	-0.0666148	-4.03	0.0007	0.01653379
RDM*RDM	0.0000111	2.59	0.0179	0.00000428
GC*RDM	0.0003656	2.56	0.0193	0.00014303

†GPCP=grass percentage in pregraze herbage mass.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-18. Least squares regression analysis of grass percentage in pregraze herbage mass for the last grazing cycle (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	17252.5483993	42.88	0.0001
Error	19	1911.2849341		
Corrected Total	23	19163.8333333		

R-Square	C.V.	GPCP† Mean
0.900266	28.72454	34.91666667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	622.5408163	6.19	0.0223
RDM§	1	12048.9423498	119.78	0.0001
RDM*RDM	1	769.3037037	7.65	0.0123
GC*RDM	1	3811.7615294	37.89	0.0001

Source	DF	Type III SS	F Value	Pr > F
GC	1	4819.68022301	47.91	0.0001
RDM	1	5568.74439568	55.36	0.0001
RDM*RDM	1	1926.46932523	19.15	0.0003
GC*RDM	1	3811.76152940	37.89	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	149.2809131	13.67	0.0001	10.92083490
GC	-1.4278804	-6.92	0.0001	0.20628546
RDM	-0.1080646	-7.44	0.0001	0.01452415
RDM*RDM	0.0000198	4.38	0.0003	0.00000453
GC*RDM	0.0007632	6.16	0.0001	0.00012398

†GPCP=grass percentage in pregraze herbage mass.

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

Table A-19. Least squares regression analysis of canopy light interception before grazing (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	8361.30247049	53.84	0.0001
Error	19	737.65586284		
Corrected Total	23	9098.95833333		

R-Square	C.V.	LIB† Mean
0.918930	8.275670	75.29166667

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	3911.91184807	100.76	0.0001
GC*GC	1	963.41962612	24.82	0.0001
RDM§	1	2432.00284806	62.64	0.0001
GC*RDM	1	1053.96814824	27.15	0.0001

Source	DF	Type III SS	F Value	Pr > F
GC	1	3393.34340550	87.40	0.0001
GC*GC	1	1476.83486388	38.04	0.0001
RDM	1	2874.65528448	74.04	0.0001
GC*RDM	1	1053.96814824	27.15	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-7.547125757	-1.12	0.2757	6.72505550
GC	2.968914071	9.35	0.0001	0.31756587
GC*GC	-0.023704682	-6.17	0.0001	0.00384342
RDM	0.025043717	8.60	0.0001	0.00291042
GC*RDM	- 0.000382986	-5.21	0.0001	0.00007351

†LIB=light interception before grazing (%).

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

Table A-20. Least squares regression analysis of canopy light interception before grazing (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	6229.85838294	28.75	0.0001
Error	18	780.14161706		
Corrected Total	23	7010.00000000		

R-Square	C.V.	LIB† Mean
0.888710	8.333422	79.00000000

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	1568.00000000	36.18	0.0001
GC*GC	1	940.16338583	21.69	0.0002
RDM§	1	2256.65708937	52.07	0.0001
RDM*RDM	1	26.26467783	0.61	0.4464
GC*RDM	1	1438.77322991	33.20	0.0001

Source	DF	Type III SS	F Value	Pr > F
GC	1	2876.16384267	66.36	0.0001
GC*GC	1	1216.84691271	28.08	0.0001
RDM	1	1041.85497975	24.04	0.0001
RDM*RDM	1	236.03189107	5.45	0.0314
GC*RDM	1	1438.77322991	33.20	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-1.503875750	-0.19	0.8506	7.87236672
GC	2.614840329	8.15	0.0001	0.32098803
GC*GC	-0.021439546	-5.30	0.0001	0.00404621
RDM	0.046785499	4.90	0.0001	0.00954241
RDM*RDM	-0.000006956	-2.33	0.0314	0.00000298
GC*RDM	-0.000469337	-5.76	0.0001	0.00008146

†LIB=light interception before grazing (%).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-21. Least squares regression analysis of canopy light interception after grazing (1988).

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	13243.0946285	181.41	0.0001
Error	21	766.5303715		
Corrected Total	23	14009.6250000		

R-Square	C.V.	LIA† Mean
0.945285	14.17394	42.62500000

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	13151.3329216	360.30	0.0001
RDM*RDM	1	91.7617068	2.51	0.1278

Source	DF	Type III SS	F Value	Pr > F
RDM	1	1110.28809793	30.42	0.0001
RDM*RDM	1	91.76170685	2.51	0.1278§

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-9.741267627	-1.96	0.0634	4.96914585
RDM	0.038935797	5.52	0.0001	0.00705970
RDM*RDM	-0.000003348	-1.59	0.1278	0.00000211

†LIA=light interception after grazing (%).
‡RDM=residual dry matter (kg ha^{-1}).
§ In the complete model P=0.03.

Table A-22. Least squares regression analysis of canopy light interception after grazing (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	15581.1576781	92.86	0.0001
Error	21	1761.8006553		
Corrected Total	23	17342.9583333		

R-Square	C.V.	LIA† Mean
0.898414	18.21263	50.29166667

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	15211.7369793	181.32	0.0001
RDM*RDM	1	369.4206988	4.40	0.0481

Source	DF	Type III SS	F Value	Pr > F
RDM	1	1957.15366040	23.33	0.0001
RDM*RDM	1	369.42069876	4.40	0.0481

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-6.486240447	-1.00	0.3284	6.48196122
RDM	0.054641901	4.83	0.0001	0.01131311
RDM*RDM	-0.000008302	-2.10	0.0481	0.00000396

†LIA=light interception after grazing (%).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-23. Least squares regression analysis of peanut rhizome mass in November 1989.

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	35065271.0180	18.91	0.0001
Error	21	19471733.4820		
Corrected Total	23	54537004.5000		

R-Square	C.V.	RM† Mean
0.642963	35.14647	2739.7500000

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	33243974.1751	35.85	0.0001
RDM*RDM	1	1821296.8429	1.96	0.1757

Source	DF	Type III SS	F Value	Pr > F
RDM	1	6297486.10298	6.79	0.0165
RDM*RDM	1	1821296.84292	1.96	0.1757§

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-169.9450526	-0.25	0.8055	681.44428412
RDM	3.0995379	2.61	0.0165	1.18933994
RDM*RDM	-0.0005829	-1.40	0.1757	0.00041593

†RM=rhizome mass (kg ha^{-1}).

‡RDM=residual dry matter (kg ha^{-1}).

§In the complete model P=0.10.

Table A-24. Least squares regression analysis of total non-structural carbohydrate concentration in rhizomes in November 1988.

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	26956.989309	10.07	0.0009
Error	21	28097.375691		
Corrected Total	23	55054.365000		

R-Square	C.V.	TNC† Mean
0.489643	30.06228	121.6750000

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	24618.608643	18.40	0.0003
RDM*RDM	1	2338.380666	1.75	0.2004

Source	DF	Type III SS	F Value	Pr > F
RDM	1	6410.013885	4.79	0.0401
RDM*RDM	1	2338.380666	1.75	0.2004§

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	25.71809786	0.85	0.4023	30.0849947
RDM	0.09355365	2.19	0.0401	0.0427420
RDM*RDM	-0.00001690	-1.32	0.2004	0.0000128

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†TNC=total non-structural carbohydrate concentration (g kg^{-1}).

‡RDM=residual dry matter (kg ha^{-1}).

§In the complete model P=0.10.

Table A-25. Least squares regression analysis of total non-structural carbohydrate concentration in rhizomes in November 1989.

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	59074.693768	38.28	0.0001
Error	21	16204.584565		
Corrected Total	23	75279.278333		
	R-Square	C.V.		TNC† Mean
	0.784740	18.86381		147.2583333

Source	DF	Type I SS	F Value	Pr > F
RDM‡	1	48341.677494	62.65	0.0001
RDM*RDM	1	10733.016274	13.91	0.0012

Source	DF	Type III SS	F Value	Pr > F
RDM	1	21524.277184	27.89	0.0001
RDM*RDM	1	10733.016274	13.91	0.0012

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	6.777160084	0.34	0.7337	19.6583469
RDM	0.181208109	5.28	0.0001	0.0343102
RDM*RDM	-0.000044750	-3.73	0.0012	0.0000120

†TNC=total non-structural carbohydrate concentration (g kg^{-1}).
‡RDM=residual dry matter (kg ha^{-1}).

Table A-26. Least squares regression analysis of mean peanut crop growth rate during the season (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	35.68787884	16.35	0.0001
Error	19	10.36883849		
Corrected Total	23	46.05671733		

R-Square	C.V.	CGR† Mean
0.774868	18.44239	4.00563187

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	7.94306347	14.55	0.0012
RDM§	1	22.93729956	42.03	0.0001
RDM*RDM	1	2.46788263	4.52	0.0468
GC*RDM	1	2.33963318	4.29	0.0523

Source	DF	Type III SS	F Value	Pr > F
GC	1	7.82372452	14.34	0.0012
RDM	1	8.72141119	15.98	0.0008
RDM*RDM	1	3.74789882	6.87	0.0168
GC*RDM	1	2.33963318	4.29	0.0523

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-0.8371965687	-1.04	0.3110	0.80437429
GC	0.0575293519	3.79	0.0012	0.01519396
RDM	0.0042765961	4.00	0.0008	0.00106978
RDM*RDM	-0.0000008740	-2.62	0.0168	0.00000033
GC*RDM	-0.0000189083	-2.07	0.0523	0.00000913

†CGR=crop growth rate (g m^{-2} d^{-1}).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).

Table A-27. Least squares regression analysis of in vitro digestible organic matter in peanut herbage consumed (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	18447.8241809	4.57	0.0094
Error	19	19167.8189511		
Corrected Total	23	37615.6431319		

R-Square	C.V.	PCD† Mean
0.490430	4.305062	737.78545833

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	142.5367380	0.14	0.7112
GC*GC	1	12286.4897548	12.18	0.0025
RDM§	1	4120.6848983	4.08	0.0576
RDM*RDM	1	1898.1127898	1.88	0.1861

Source	DF	Type III SS	F Value	Pr > F
GC	1	13176.5849556	13.06	0.0018
GC*GC	1	14064.5698258	13.94	0.0014
RDM	1	863.0180701	0.86	0.3666¶
RDM*RDM	1	1898.1127898	1.88	0.1861#

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	682.0462046	23.91	0.0001	28.53106414
GC	5.1021383	3.61	0.0018	1.41175828
GC*GC	-0.0728223	-3.73	0.0014	0.01950343
RDM	-0.0364655	-0.92	0.3666	0.03942594
RDM*RDM	0.0000190	1.37	0.1861	0.00001383

†PCD=peanut consume in vitro organic matter digestibility (%).
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).
¶In the complete model P=0.11.
#In the complete model P=0.08.

Table A-28. Least squares regression analysis of crude protein in peanut herbage consumed (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	21198.4190154	11.11	0.0002
Error	20	12723.1153155		
Corrected Total	23	33921.5343310		

R-Square	C.V.	PCCP† Mean
0.624925	14.26161	176.85329167

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	10089.4157917	15.86	0.0007
GC*GC	1	4193.6458371	6.59	0.0184
RDM§	1	6915.3573866	10.87	0.0036

Source	DF	Type III SS	F Value	Pr > F
GC	1	1149.68349201	1.81	0.1939¶
GC*GC	1	3460.46545724	5.44	0.0302
RDM	1	6915.35738659	10.87	0.0036

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	214.1246540	11.31	0.0001	18.92720579
GC	1.4981278	1.34	0.1939	1.11440085
GC*GC	-0.0359646	-2.33	0.0302	0.01542021
RDM	-0.0213092	-3.30	0.0036	0.00646311

†PCCP=crude protein concentration (g kg^{-1}) in peanut consumed.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).
¶In the complete model P=0.40.

Table A-29. Least squares regression analysis of in vitro digestible organic matter in grass herbage consumed (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	46481.9198786	2.71	0.0608
Error	19	81322.2086443		
Corrected Total	23	127804.1285230		

R-Square	C.V.	GD† Mean
0.363697	13.70088	477.50670833

Source	DF	Type I SS	F Value	Pr > F
GC†	1	519.8707802	0.12	0.7313
GC*GC	1	21143.5236871	4.94	0.0386
RDM§	1	5467.4254616	1.28	0.2724
GC*RDM	1	19351.0999497	4.52	0.0468

Source	DF	Type III SS	F Value	Pr > F
GC	1	3487.7964718	0.81	0.3780¶
GC*GC	1	16955.1857601	3.96	0.0611
RDM	1	24579.8224536	5.74	0.0270
GC*RDM	1	19351.0999497	4.52	0.0468

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	533.9303787	8.37	0.0001	63.80760223
GC	2.8790197	0.90	0.3780	3.18931088
GC*GC	-0.0797905	-1.99	0.0611	0.04008924
RDM	-0.0725573	-2.40	0.0270	0.03027747
GC*RDM	0.0016547	2.13	0.0468	0.00077820

†GD=in vitro digestible organic matter (g kg^{-1}) in grass consumed.
‡GC=grazing cycle (d).
§RDM=residual dry matter (kg ha^{-1}).
¶In the complete model P=0.39.

Table A-30. Least squares regression analysis of in vitro digestible organic matter in total herbage consumed (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	4	56299.2889717	5.26	0.0050
Error	19	50819.9051453		
Corrected Total	23	107119.1941170		
	R-Square	C.V.		CCD† Mean
	0.525576	8.279376		624.65829167

Source	DF	Type I SS	F Value	Pr > F
GC‡	1	13200.5522087	4.94	0.0387
GC*GC	1	11420.4941261	4.27	0.0527
RDM§	1	16961.1116309	6.34	0.0209
GC*RDM	1	14717.1310061	5.50	0.0300

Source	DF	Type III SS	F Value	Pr > F
GC	1	5740.3473214	2.15	0.1593¶
GC*GC	1	11492.3526177	4.30	0.0520
RDM	1	835.8409629	0.31	0.5827#
GC*RDM	1	14717.1310061	5.50	0.0300

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	555.5841725	11.01	0.0001	50.44112537
GC	3.6935005	1.46	0.1593	2.52121102
GC*GC	-0.0656908	-2.07	0.0520	0.03169131
RDM	-0.0133799	-0.56	0.5827	0.02393491
GC*RDM	0.0014430	2.35	0.0300	0.00061518

†CCD=in vitro digestible organic matter (g kg^{-1}) in total herbage consumed.

‡GC=grazing cycle (d).

§RDM=residual dry matter (kg ha^{-1}).

¶In the complete model P=0.15.

#In the complete model P=0.34.

Table A-31. Least squares regression analysis of crude protein in total herbage consumed (1989).

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	6820.36292301	4.39	0.0256
Error	21	16327.97345832		
Corrected Total	23	23148.33638133		

R-Square	C.V.	CCP† Mean
0.294637	19.54897	142.63716667

Source	DF	Type I SS	F Value	r > F
GC‡	1	595.80533718	0.77	0.3913
GC*GC	1	6224.55758583	8.01	0.0100

Source	DF	Type III SS	F Value	Pr > F
GC	1	5134.26142743	6.60	0.0179
GC*GC	1	6224.55758583	8.01	0.0100

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	112.6240223	6.61	0.0001	17.04803844
GC	3.1540923	2.57	0.0179	1.22741634
GC*GC	-0.0481185	-2.83	0.0100	0.01700649

†CCP=crude protein concentration in total herbage consumed (g kg^{-1}).

‡GC=grazing cycle (d).

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BIOGRAPHICAL SKETCH

Jose Alfonso Ortega-Santos was born October 29, 1959, in Gonzalez, Tam., Mexico. His parents are Alfonso Ortega-Sanchez and Aurora Santos. He graduated in May 1981 with the degree of Ingeniero Agronomo Zootecnista from the Facultad de Agronomia in Victoria, Tam., Mexico. Two years before completion of his undergraduate studies, he obtained the opportunity to join a team of forage researchers working for the state government in the subtropical region of Tamaulipas, Mexico. In November 1985 he received the Master of Science degree in animal production from the Universidad Autonoma Agraria "Antonio Narro." Following completion of his master's degree program he worked in the forage research program of the National Institute of Forestry, Agronomy, and Livestock Research (INIFAP) in the tropical region of the Mexican Gulf Coast. In May 1987 he began a Ph.D. program in the Agronomy Department at the University of Florida. He is married to Caty and they have three children, Alfonso, Alejandra, and Alfonsina.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lynn E. Sollenberger

Lynn E. Sollenberger, Chairman
Assistant Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

K.H. Quesenberry

Kenneth H. Quesenberry, Cochairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John E. Moore

John E. Moore
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William D. Pitman

William D. Pitman
Associate Professor of Agronomy

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Jerry M. Bennett

Jerry M. Bennett
Associate Professor of Agronomy

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Gordon M. Prine

Gordon M. Prine
Professor of Agronomy

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Jack L. Fry

August 1990

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